



NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

**DEVELOPING A MARKOV MODEL FOR
FORECASTING END STRENGTH OF SELECTED
MARINE CORPS RESERVE (SMCR) OFFICERS**

by

Anthony D. Licari
March 2013

Thesis Advisor:
Co-Advisor:

Chad W. Seagren
Jonathan Price

Approved for public release; distribution is unlimited

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			<i>Form Approved OMB No. 0704-0188</i>	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE March 2013	3. REPORT TYPE AND DATES COVERED Master's Thesis	
4. TITLE AND SUBTITLE DEVELOPING A MARKOV MODEL FOR FORECASTING END STRENGTH OF SELECTED MARINE CORPS RESERVE (SMCR) OFFICERS			5. FUNDING NUMBERS	
6. AUTHOR(S) Anthony D. Licari				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol number ____N/A____.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited			12b. DISTRIBUTION CODE A	
13. ABSTRACT (maximum 200 words) <p>This thesis develops Markov models for prior service (PS) and non-prior service (NPS) Selected Marine Corps Reserve (SMCR) officers. Data were collected from the Total Force Data Warehouse (TFDW) for all SMCR officers who served between September 30, 1998 and October 31, 2012. Determining SMCR officer end strength is necessary for reserve manpower planners to balance the force structure, minimize personnel excesses and shortages that impact training and labor costs, and to manage career progression.</p> <p>The PS model validation and analysis show that an aggregate monthly rate and unique monthly transition rates produce similar results. Both models perform well and they are consistent and accurate. Consistency and accuracy are important because budget planners and recruiting command rely on manpower estimates during the fiscal year. Overall, the aggregate monthly rate models perform slightly better than the unique monthly transition rate models with respect to end strength prediction, average strength prediction, and cost. More importantly, all four PS models performed better than the current Reserve Affairs model.</p> <p>We are unable to validate the NPS officer model. Since there are so few observations, the transition rates are suspect because they have a very high variance.</p>				
14. SUBJECT TERMS Marine Corps Reserve, Markov, Officers, transition probabilities, manpower planning.			15. NUMBER OF PAGES 73	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UU	

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

**DEVELOPING A MARKOV MODEL FOR FORECASTING END STRENGTH
OF SELECTED MARINE CORPS RESERVE (SMCR) OFFICERS**

Anthony D. Licari
Major, United States Marine Corps
B.S., United States Naval Academy, 1998
MBA, University of Maryland, 2009

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

**NAVAL POSTGRADUATE SCHOOL
March 2013**

Author: Anthony D. Licari

Approved by: Chad W. Seagren
Thesis Advisor

Jonathan Price
Thesis Co-Advisor

William Gates
Dean, Graduate School of Business and Public Policy

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

This thesis develops Markov models for prior service (PS) and non-prior service (NPS) Selected Marine Corps Reserve (SMCR) officers. Data were collected from the Total Force Data Warehouse (TFDW) for all SMCR officers who served between September 30, 1998 and October 31, 2012. Determining SMCR officer end strength is necessary for reserve manpower planners to balance the force structure, minimize personnel excesses and shortages that impact training and labor costs, and to manage career progression.

The PS model validation and analysis show that an aggregate monthly rate and unique monthly transition rates produce similar results. Both models perform well, and they are consistent and accurate. Consistency and accuracy are important because budget planners and recruiting command rely on manpower estimates during the fiscal year. Overall, the aggregate monthly rate models perform slightly better than the unique monthly transition rate models with respect to end strength prediction, average strength prediction, and cost. More importantly, all four PS models performed better than the current Reserve Affairs model.

We are unable to validate the NPS officer model. Since there are so few observations, the transition rates are suspect because they have a very high variance.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

I.	INTRODUCTION.....	1
A.	PURPOSE.....	1
B.	BACKGROUND	1
1.	End Strength.....	1
2.	Department of Defense Total Force Policy	4
C.	SCOPE AND METHODOLOGY	6
D.	ORGANIZATION OF STUDY	7
II.	RESERVE ORGANIZATION AND FORCE STRUCTURE	9
A.	INTRODUCTION.....	9
B.	COMPONENTS.....	9
1.	Ready Reserve	9
a.	<i>Selected Reserve (SelRes)</i>	9
b.	<i>Individual Ready Reserve (IRR)</i>	10
2.	Standby Reserve.....	10
3.	Retired Reserve	11
C.	PARTICIPATION REQUIREMENTS	11
D.	ACCESSIONS	12
1.	SelRes Recruiting Missions	13
2.	Incentives	14
E.	CHAPTER SUMMARY.....	14
III.	LITERATURE REVIEW	15
A.	INTRODUCTION.....	15
B.	NON-MILITARY MANPOWER STUDIES USING MARKOV MODELS	16
C.	DEVELOPMENT OF A MARKOV MODEL FOR FORECASTING CONTINUATION RATES FOR ENLISTED PRIOR SERVICE AND NON-PRIOR SERVICE PERSONNEL IN THE SELECTIVE MARINE CORPS RESERVE (SMCR)	17
D.	ANALYSIS OF THE U.S. MARINE CORPS' STEADY STATE MARKOV MODEL FOR FORECASTING ANNUAL FIRST-TERM ENLISTED CLASSIFICATION REQUIREMENTS	18
E.	FORECASTING RETENTION IN THE UNITED STATES MARINE CORPS RESERVE	18
F.	CHAPTER SUMMARY.....	20
IV.	DATA AND METHODOLOGY	21
A.	INTRODUCTION.....	21
B.	DATA SOURCES	21
1.	Reserve Affairs Personnel Plans, Policy, and Programming (RAP-2)	21
a.	<i>Total Force Data Warehouse (TFDW)</i>	21
2.	Descriptive Variables.....	21

a.	<i>Present Grade Code (grade)</i>	22
b.	<i>Mandatory Drill Participation Stop Date (MDSD)</i>	22
c.	<i>Pay Entry Base Date (PEBD)</i>	22
d.	<i>Total Satisfactory Years (sat_yrs)</i>	22
e.	<i>Anniversary Date (annv_date)</i>	23
f.	<i>Reserve Component Code (rcompcode)</i>	23
g.	<i>Reserve Reporting Unit Code (rruc)</i>	23
h.	<i>Years of Commissioned Service (yrs)</i>	23
i.	<i>Armed Forces Active Duty Base Date (afadbd)</i>	23
j.	<i>Date Accepted First Commission (dafc)</i>	24
k.	<i>Satisfactory Months (sat_months)</i>	24
l.	<i>Source of Entry (soe)</i>	24
m.	<i>Fiscal Year (fy)</i>	24
C.	DESCRIPTIVE STATISTICS	25
D.	MARKOV MODEL THEORY	26
E.	FIXED INVENTORY MODEL	26
1.	Methodology	27
a.	<i>Conceptual Model</i>	27
b.	<i>Transition Matrix</i>	28
c.	<i>Fixed Inventory Equation</i>	28
F.	LIMITATIONS OF THE MODELS	29
G.	SUMMARY	29
V.	MODEL IMPLEMENTATION AND VALIDATION	31
A.	NPS AND PS EXCEL AGGREGATE MONTHLY RATE MODELS	31
1.	Main Tab	32
2.	Attrition_K4 Tab	32
3.	Growth Tabs	33
4.	Growth Rate Tabs	33
B.	NPS MODEL WITH UNIQUE MONTHLY TRANSITION RATES	33
1.	Monthly Transition Matrices	33
2.	Attrition Input Tab	34
3.	Growth_K4 Tab	35
C.	MODEL VALIDATION	35
1.	FY11 Prior AC Aggregate Monthly Transition Rate Model	36
2.	FY11 Prior AC Unique Monthly Transition Rates Model	36
3.	FY12 Prior AC Aggregate Monthly Transition Rate Model	37
4.	FY12 Prior AC Unique Monthly Transition Rates Model	38
D.	MODEL COMPARISONS	39
E.	MODEL COMPARISON USING COST ESTIMATES	42
F.	FORECASTING CONTINUATION BEHAVIOR FOR PRIOR RC MARINES	44
G.	SUMMARY	45
VI.	CONCLUSION AND RECOMMENDATION	47
A.	CONCLUSION	47
B.	RECOMMENDATIONS/FUTURE RESEARCH	48

LIST OF REFERENCES	49
INITIAL DISTRIBUTION LIST	51

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF FIGURES

Figure 1.	Marine Corps Reserve Company Grade Officer Strength	3
Figure 2.	SMCR Unit End Strength (by grade), August 2012	4
Figure 3.	NPS Reserve Officer Accessions (FY04-FY12).....	5
Figure 4.	Components of the Marine Corps Reserve	11
Figure 5.	Marine Corps Reserve Officers Average Satisfactory Years by Pay Grade....	23
Figure 6.	Observations by Rank	25
Figure 7.	Conceptual Markov Model	27
Figure 8.	Aggregate Monthly Rate Models Main Tab	31
Figure 9.	Transition Matrix and Inventory Vectors	32
Figure 10.	Main Tab (300 states with unique monthly transition rates)	33
Figure 11.	October Transition Matrix (P_Oct).....	34
Figure 12.	Attrition Input Tab (continuation rates).....	34
Figure 13.	Growth K4 Tab	35
Figure 14.	FY11 Aggregate Rate v. Actual Strength	36
Figure 15.	FY11 Unique Monthly Transition Rates v. Actual Strength	37
Figure 16.	FY12 Aggregate Rate v. Actual Strength	38
Figure 17.	FY12 Unique Monthly Transition Rates v. Actual Strength	39
Figure 18.	FY11 SMCR Officer Aggregate v. Unique Monthly Transition Rates (within year end strength predictions)	40
Figure 19.	FY12 SMCR Officer Aggregate v. Unique Monthly Transition Rates (within year end strength predictions)	41
Figure 20.	Prior RC Officer Attrition Rates v. Aggregate Prior AC Loss Rate	45

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

Table 1.	Minimum Reserve Participation Requirements	12
Table 2.	Sequences by FY and Month	25
Table 3.	Model Comparison without Monthly Inventory Updates	39
Table 4.	Model Comparison with Monthly Inventory Updates	41
Table 5.	Reserve Personnel, Marine Corps Pay Groups	42
Table 6.	Inactive Duty Training (IDT) Estimated Costs per Model	43
Table 7.	Annual Training (AT) Estimated Costs per Model.....	43
Table 8.	Summary of Costs per Model	44

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

AC	Active Component
AFADBD	Armed Forces Active Duty Base Date
ADT	Active Duty Training
AFQT	Armed Forces Qualification Test
annv_date	Anniversary Date
AR	Active Reserve
ARIMA	Autoregressive Integrated Moving Average
ASL	Active Status List
AT	Annual Training
CNA	Center for Naval Analysis
DAFC	Date Accepted First Commission
DoD	Department of Defense
DOR	Date of Rank
FMCR	Fleet Marine Corps Reserve
FY	Fiscal Year
IADT	Initial Active Duty for Training
IIADT	Incremental Initial Active Duty for Training
IDT	Inactive Duty Training
IMA	Individual Mobilization Augmentee
IRR	Individual Ready Reserve
ISL	Inactive Status List

JJAS	June-September
MAPE	Mean Absolute Percentage Error
M&RA	Manpower and Reserve Affairs
MARFORRES	Marine Forces Reserve
MCRAMM	Marine Corps Reserve Administrative Management Manual
MCR	Marine Corps Reserve
MCRC	Marine Corps Recruiting Command
MCTFS	Marine Corps Total Force System
MDSD	Mandatory Drill Stop Date
MI	Manpower Information
MOS	Military Occupational Specialty
MSO	Military Service Obligation
NCO	Non-Commissioned Officer
NDAA	National Defense Authorization Act
NPS	Non-Prior Service
OAB	Officer Affiliation Bonus
OCS	Officer Candidates School
OSO	Officer Selection Officer
PCS	Permanent Change of Station
PEBD	Pay Entry Base Date
PII	Personally Identifiable Information
PMOS	Primary Military Occupational Specialty
POM	Program Objective Memorandum

PS	Prior Service
PSR	Prior Service Recruiter
P&R	Programs and Resources
QSN	Quota Serial Number
RA	Reserve Affairs
RAP	Reserve Affairs Personnel Policy, Plans, and Programming
RASL	Reserve Active Status List
RC	Reserve Component
rcompcode	Reserve Component Code
ROCP	Reserve Officer Commissioning Program
ROPMA	Reserve Officer Personnel Management Act
RPMC	Reserve Personnel Marine Corps
RRUC	Reserve Reporting Unit Code
RRRTF	Reserve Recruiting and Retention Task Force
RUC	Reporting Unit Code
sat_months	Satisfactory Months
sat_years	Satisfactory Years
SECDEF	Secretary of Defense
SECNAV	Secretary of the Navy
SelRes	Selected Reserve
SFAAT	Security Force Assistance and Advisor Teams
SMCR	Selected Marine Corps Reserve (Units)

SOE	Source of Entry
TFDW	Total Force Data Warehouse
USMC	United States Marine Corps
YCS	Years of Commissioned Service

ACKNOWLEDGMENTS

I owe a great deal of thanks and love to my wife, Jennifer, and my son, James, for their patience and understanding while I completed this thesis. You both were a great inspiration, and it was badly needed at times. I also want to thank my parents, Roy and Yvette, for always encouraging my education. Congratulations to my brother, Kane, for never giving up on his goals and for working hard to help other people every day.

I give my sincere thanks to Lieutenant Colonel Jonathan Price and Major Chad Seagren for serving as advisors on my thesis. It was a lot of work and long hours. I could not have done it without both of you.

Also, thanks to Captain Nick Pergar, Captain Eric Meyers, Captain Doug Toulotte, Captain Jeremy Hall, Master Sergeant O’Leary, Gunnery Sergeant Woo and the entire Reserve Affairs and MCRC team for making my life a lot easier.

I owe a great deal of thanks Lieutenant General Milstead, Colonel Jeff Peterson, Colonel Steve Neary, Colonel Mike Bowersox, Lieutenant Colonel Shawn Wonderlich, Lieutenant Colonel Fran Ippolito-Bennett, Lieutenant Colonel John “Sean” Meyers and Mr. Steve Wittle for supporting me and giving me a lot of good advice over the years.

Thanks to Professors Mark Eitelberg, David Henderson, Jesse Cunha, Aruna Apte, Simona Tick, Elda Pema, Dina Shatnawi, Marco DiRenzo, Bill Hatch, Ben Roberts, and Mike Dixon for all the extra help, humor and guidance.

Thanks to Sally Baho for editing my research papers. You were instrumental in making my papers better.

Thanks to Professor Lisa Mignone of Brown University for all of her help with Roman and Greek history. Your assistance made my military history and sociology papers a lot better.

Last, thanks to Dr. Michelle Dolfini-Reed and SgtMaj Gary Lee USMC (Ret.) at the Center for Naval Analysis (CNA) for all of your assistance over the years.

PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

A. PURPOSE

The primary purpose of this thesis is to develop and validate a Markov model for Selected Marine Corps Reserve (SMCR) unit officers. This model will be utilized as a tool for accession and end strength planning to improve forecasts beyond the current fiscal year (FY). Projecting officer inventory is necessary for reserve manpower planners to balance the force while minimizing personnel excesses and shortages which impact training and labor costs, as well as career progression. The current model used by Director, Reserve Affairs (RA) produces large inaccuracies of nearly 6% in officer end strength forecasts. Additionally, the current model inadequately addresses changes in the officer program mix and does not support the development of accurate longevity tables necessary for in-year and Program Objective Memorandum (POM) costing. A secondary purpose of this thesis is to determine the best method to forecast continuation behavior for Reserve Officer Commissioning Program (ROCP) accessions given limited data.

B. BACKGROUND

1. End Strength

Each year, Congress mandates the Marine Corps Selective Reserve (SelRes) end strength in section 411 of the National Defense Authorization Act (NDAA). Since FY04, the SelRes end strength requirement has remained at 39,600 Marines.¹ Congress provides a 3% (plus or minus) variance that allows manpower planners to meet emerging operational requirements or budget constraints.² However, Congress has authorized only a 2% variance to the Secretary of the Navy and requires any greater variance receive Secretary of Defense approval. Using the current (FY13) end strength authorization allows the Marine Corps the flexibility of maintaining end strength between a ceiling of

¹ *National Defense Authorization Act*, Public Law 108-136, *U.S. Statutes at Large* 117 (2003): 1392, codified at U.S. Code (2003), §411(a)(4).

² *National Defense Authorization Act*, Public Law 110-181, *U.S. Statutes at Large* 122 (2008): 22, codified at U.S. Code (2008), §417.

40,788 Marines and a floor of 38,412 Marines. Given budget constraints, the Deputy Commandant, Manpower and Reserve Affairs (M&RA) has capped SelRes end strength on September 30 of each fiscal year at no more than 39,600. Furthermore, the Deputy Commandant, Programs and Resources budgets for an average strength near this limit. Thus, the Reserve Personnel Marine Corps (RPMC) appropriation does not provide for the end strength flexibility authorized in the NDAA and planners typically focus on maintaining a narrower monthly tolerance of 1% variance from authorized end strength (< 396 Marines).

From 2007 - 2009, the Marine Corps did not attain its SelRes end strength. This difficulty was caused by limited manpower resources to support the Active Component (AC) 202,000 build (“202k”), programmatic officer inventory shortfalls, and erroneous accession planning. The most notable reason for this end strength shortfall is that the SelRes officer inventory structure has been critically short of company grade officers since 1997 (Figure 1).

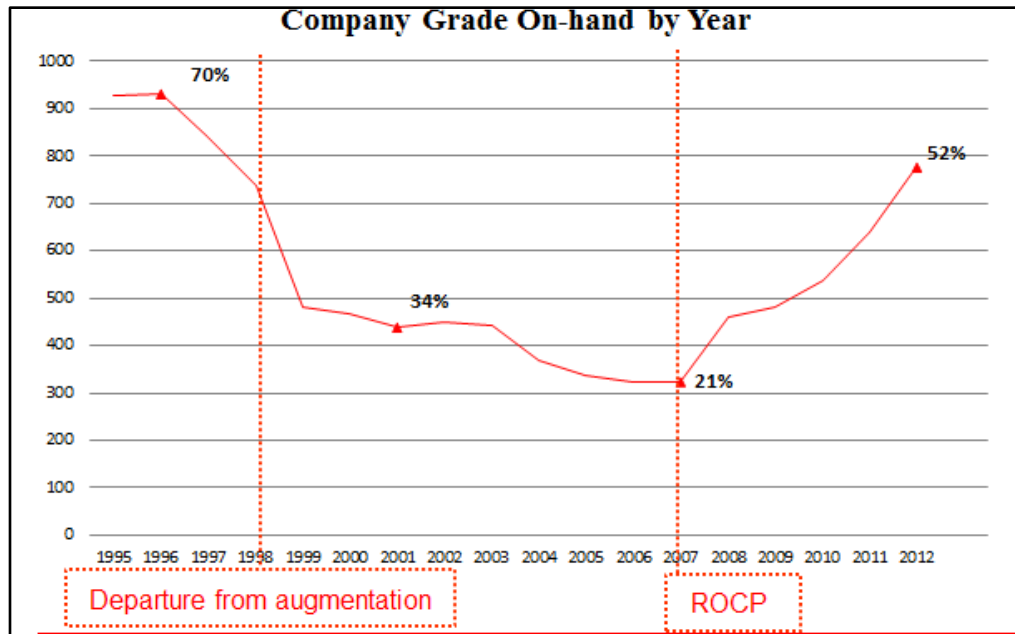


Figure 1. Marine Corps Reserve Company Grade Officer Strength³

This shortfall caused manpower planners to overcompensate in several areas. The Marine Corps accessed more non-prior service (NPS) enlisted Marines while retaining more senior field grade officers in an attempt to meet staffing shortfalls. The net result yielded an unbalanced SelRes with too many senior officers, unobligated noncommissioned officers (NCO) and not enough company grade officers and Staff NCOs.

³ Eric W. Meyers, *Reserve Officer Manpower Brief as of 30 September 2012* (Quantico, VA: U.S. Department of the Navy, 2012).

	Grade	NARR	On-Hand	Shortfall/ Overage	Fill %
Enlisted	E1-E3	14,899	17,671	2,772	119%
	E4	6,752	5,928	-824	88%
	E5	4,178	3,963	-215	95%
	E6	1,733	1,073	-660	62%
	E7	832	549	-283	66%
	E8	423	246	-177	58%
	E9	143	101	-42	71%
Enlisted Total		28,960	29,531	571	102%
Officer	O1-02	808	274	-534	34%
	O3	754	500	-254	66%
	O4	425	392	-33	92%
	O5	259	312	53	120%
	O6	46	60	14	130%
	W1	35	9	-26	26%
	W2	155	101	-54	65%
	W3	66	46	-20	70%
	W4	16	17	1	106%
	W5	3	5	2	167%
Officer Total		2,567	1,716	-851	67%
Grand Total		31,527	31,247	-280	99%

Figure 2. SMCR Unit End Strength (by grade), August 2012⁴

2. Department of Defense Total Force Policy

The Department of Defense's (DoD) total force policy requires that the reserve component (RC) be structured to have the same capabilities for like units resident in the active force, and to provide the means for rapid augmentation and expansion of the Marine Corps during a national emergency. This policy of designing reserve units to replicate AC units is commonly known as *mirror imaging*. *Mirror imaging* implicitly requires that the Marine Corps Reserve (MCR) manage its officer population similarly to the AC without the benefit of relocating officers via permanent change of station (PCS) moves.

The Marine Corps has also changed the way in which it procures officers. Traditionally, the Marine Corps staffed SMCR units only with officers who previously served as an AC Marine officer. This approach to officer procurement led to a steady decline in reserve company grade officers after the 1990s drawdown. However, even

⁴ Nick Pergar, *Reserve Manpower Brief as of 30 September 2012* (Quantico, VA: U.S. Department of the Navy, 2012).

shortfalls of 15-30% were common throughout the 1980s and early 1990s. The lack of company grade officers was further exacerbated when the AC suspended competitive augmentation in 1998 and experienced historically high retention rates among its officers post-9/11.⁵

In FY06, the Marine Corps implemented the Reserve Officer Commissioning Program (ROCP) to directly commission officers into the RC as second lieutenants. The program has steadily built the company grade officer ranks of the RC. Figure 3 shows non-prior service (NPS) reserve officer accessions since FY04. In this context, reserve officers are considered NPS accessions because they are accessed by a MCRC Officer Selection Officer (OSO) or other MCRC commissioning programs, having not previously attended the officer candidate course (OCS). They may, and often do, have prior enlisted service.

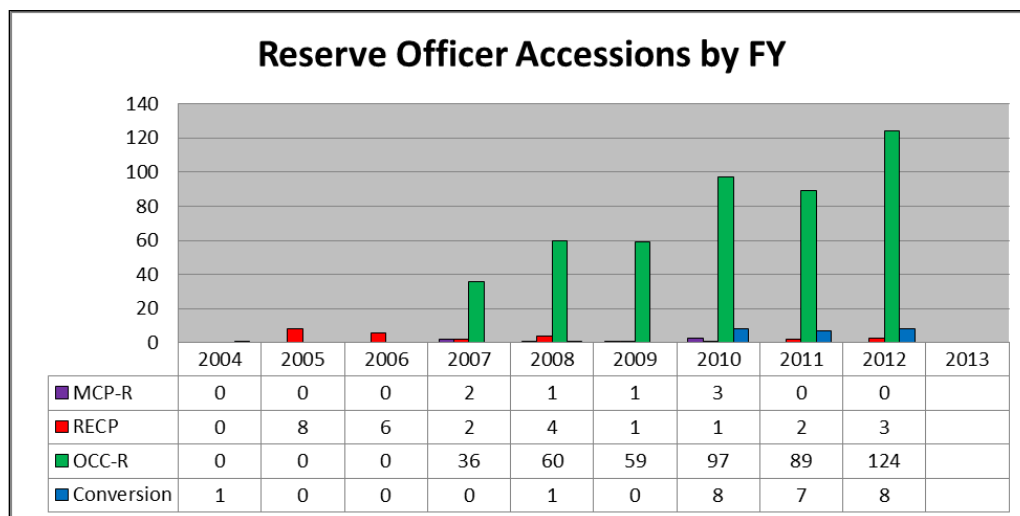


Figure 3. NPS Reserve Officer Accessions (FY04-FY12)

Furthermore, the Commandant of the Marine Corps has transitioned the RC from a strategic to an operational asset. In reality, the RC has been employed operationally for the past decade so this change was expected. However, it means that the RC could

⁵ Stephen J. Reamy, "Optimal Career Progression Of Ground Combat Arms Officers In The Marine Reserve," (Master's thesis, Naval Postgraduate School, 2012), 2.

continue to activate and deploy more frequently in support of expeditionary combat and contingency operations, theater security cooperation, and Security Force Assistance and Advisor Teams (SFAAT). This will most likely affect the continuation and retention behavior of reserve Marines, including officers.

Last, the Marine Corps is likely to experience a period of fiscal austerity that will negatively impact its ability to retain quality officers. The current political climate is hostile to more defense spending and is unlikely to change in the near future. Also, as the war in Afghanistan comes to an end, the Marine Corps will have less funding available and more scrutiny will be placed on its current spending practices. Bonuses and other continuation and retention tools will require optimization to maximize effectiveness while also remaining within these budget constraints.

In light of these changes, the Director, Reserve Affairs ordered implementation of billet-level management and revision of the SMCR officer manpower model. The current planning model uses a moving average that is no longer adequate because it produces inaccurate officer end strength forecasts and over-aggregates officer inventories. The development of a Markov model will enable manpower planners to accurately model available manpower assets, forecast accession requirements, and project officer end strength. A Markov model will allow Reserve Affairs Personnel Plans, Policy, and Programming (RAP-2) to analyze personnel policies more efficiently and accurately, allow it to forecast end strength impacts in various budgetary constraint environments, and to communicate recruiting, career and manpower assignment policies, and retention missions to Marine Corps Recruiting Command (MCRC) and Marine Forces Reserve (MARFORRES).

C. SCOPE AND METHODOLOGY

The goal of this thesis is to develop and validate a Markov model for Selected Marine Corps Reserve (SMCR) Officers. This model will be utilized as a tool for accession, alignment, and end strength planning to improve forecasts beyond the current fiscal year (FY). The current moving average model does not provide an accurate projection for the NPS and PS officer populations. The data used for this research was

acquired from the Total Force Data Warehouse (TFDW) and includes all reserve officer personnel accessions and losses from the period of September 30, 1998 to October 31, 2012.

D. ORGANIZATION OF STUDY

Chapter II is an introduction to the Marine Corps Reserve force structure and organization. Chapter III is a literature review of Markov model theoretical framework and prior research on Marine Corps Reserve manpower issues. Chapter IV is dedicated to the data and methodology. Chapter V shows the model implementation and validation for this study. Chapter VI offers conclusions and recommendations.

THIS PAGE INTENTIONALLY LEFT BLANK

II. RESERVE ORGANIZATION AND FORCE STRUCTURE

A. INTRODUCTION

The mission of the Marine Corps Reserve (MCR) is to augment and reinforce the active component with both qualified individuals and trained units during a time of national emergency, war, or when the nation's national security is at risk.⁶ As depicted in Figure 4, the MCR is categorized into three major components: the Ready Reserve, Standby Reserve, and Retired Reserve.

B. COMPONENTS

1. Ready Reserve

The Ready Reserve is composed of the Selected Reserve (SelRes) and the Individual Ready Reserve (IRR) and is organized to serve as the nation's crisis contingency during times of war or national emergency.⁷

a. Selected Reserve (SelRes)

The SelRes consists of the Active Reserve (AR), Selected Marine Corps Reserve (SMCR) units, Individual Mobilization Augmentees (IMA), and Marines undergoing Initial Active Duty for Training (IADT). Approximately 40% of the Ready Reserve and nearly all drilling reservists fall into this category of the RC. Furthermore, approximately 80% of Marines in the SelRes serve in SMCR units in which their minimum service includes drilling one weekend out of the month and two weeks out of the year. IMAs are drilling reservists that augment active component organizations, which may require temporary active duty in support of either combat military operations or training roles.⁸ The focus of this thesis is limited to Marine Officers in the SMCR units.

⁶ *Marine Corps Reserve Administration Management Manual* (Quantico, VA: Reserve Affairs, 2010).

⁷ Ibid, 1–3.

⁸ Ibid, 1–2.

b. Individual Ready Reserve (IRR)

The IRR is a CMC manpower pool principally consisting of individuals who are available for mobilization; have had training; have previously served in the active forces or in the SelRes; and who are in one of the following categories:

- Have not completed their Military Service Obligation (MSO).
- Have completed their MSO and are in the Ready Reserve by voluntary agreement.
- Have not completed their MSO and are mandatory participants, but are authorized to transfer to the IRR.

2. Standby Reserve

The Standby Reserve consists of Marines who are unable to meet minimum participation requirements of the Ready Reserve and desire to maintain their affiliation, are bound by contractual obligation, or are officers who have failed to resign their commission. The Standby Reserve is comprised of two categories: Active Status List (ASL) and Inactive Status List (ISL). These individuals are not required to train and are not members of units; however, they may be mobilized as needed to fill manpower requirements for specific skills. The ASL of the Standby Reserve is primarily those reservists who have been unable to participate in the reserve on a regular basis due to civilian employment hardship or other personal issues. Members of the ASL still remain eligible for promotion and must complete their annual reserve point participation requirements in order to be retained in an active status. Key federal employees, such as congressmen who serve in the Marine Corps Reserve, also fall under this category.

The ISL consists solely of officers who have met their requirements of service obligation but failed to meet their minimum annual participation point requirements, and desire to remain affiliated with the Reserve, fail to respond to annual correspondence requirements, or are beyond service limitations to remain in an active status. Reservists in the ISL are not eligible to receive pay, promotion, or retirement benefits.⁹ Both the ASL and the ISL categories are not relevant to this study.

⁹ MCO 1001R.1K, 1-4.

3. Retired Reserve

The retired reserve consists of those Marines who have either requested or been approved for retirement. Marines within the Retired Reserve may be recalled to active duty under U.S. Code 10, paragraph 688. The retired reserve comprises the Fleet Marine Corps Reserve (FMCR), the Retired Reserve Awaiting Pay, the Retired Reserve in Receipt of Retired Pay, and the Regular Retired List. This category is not relevant to this study.

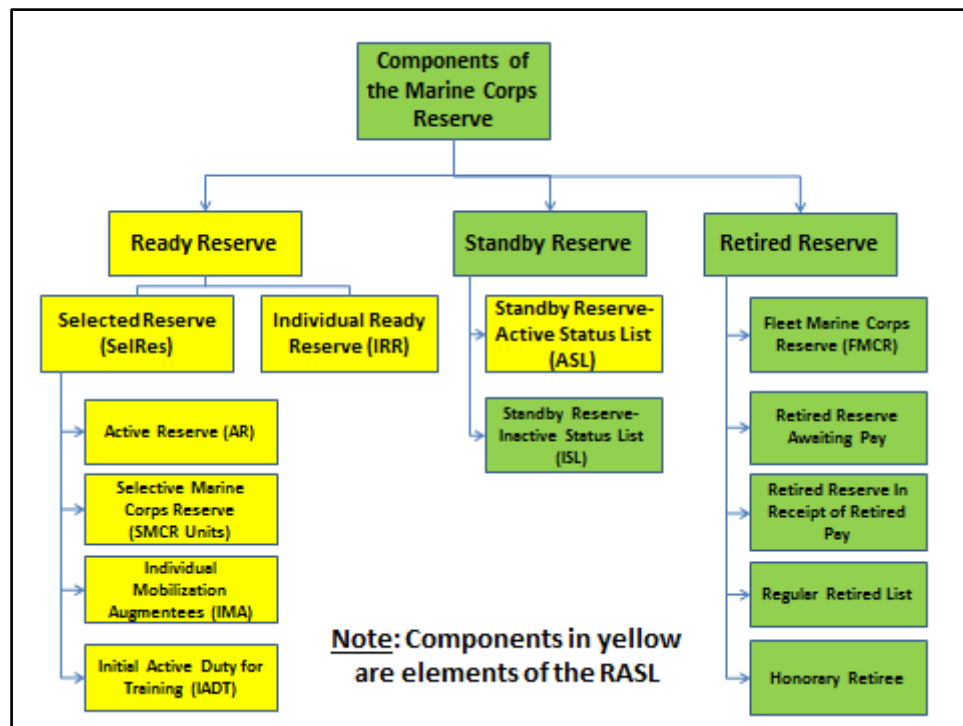


Figure 4. Components of the Marine Corps Reserve

C. PARTICIPATION REQUIREMENTS

Jonathan Price explains that “each member of the Marine Corps Reserve in an active status is subject to varying annual participation requirements that can range as high as a minimum 48 periods of inactive duty training (IDT) and 14 days of active duty

training (ADT).”¹⁰ For purposes of this study, we are only concerned with the SMCR requirements since we are modeling SMCR officers. An SMCR officer must complete a minimum of 48 periods of IDT and 14 days of ADT to satisfy his or her annual participation requirement. According to the MCRAMM, SMCR unit members can combine any combination of ADT, incremental initial active duty for training (IIADT), IADT, attendance at a formal school, or full time AD to fulfill the 14 days AT requirement per FY.¹¹

Category	IDT	ADT	Points	Other
SMCR	48	14	NA	
IMA	48	12	NA	
IADT	NA	Varies by MOS	NA	
IRR	0	0	27	Muster Duty
ASL	0	0	27	
AR	NA	NA	NA	Active Duty

Table 1. Minimum Reserve Participation Requirements¹²

D. ACCESSIONS

Representatives from M&RA, MARFORRES, and the Marine Corps Recruiting Command (MCRC) meet semi-annually to assess the current and future FY non-prior service (NPS) and prior service recruiting missions. The meetings primarily deal with accession planning, policy changes, assignment policy, career development, bonus amounts, military occupational specialty (MOS) eligibility, and any other recruiting or retention-related topics. The first meeting in December includes a reporting unit code (RUC) and MOS-level review of the enlisted NPS accession plan. The second meeting in

¹⁰ Jonathan D. Price, “Effects of Activation on Selected Marine Corps Reserve Prior Service Enlisted Continuation Rates in the Post-9/11 Era,” (Master’s thesis, Naval Postgraduate School, 2010), 19.

¹¹ MCO 1001R.1K, 4-39.

¹² MCO 1001R.1K, Table 9–1.

January is known as the Reserve Recruiting and Retention Task Force (RRRTF). It is a forum meant to discuss recruiting and retention related topics, to provide a chance to assess the current FY recruiting mission after the first quarter, to finalize the next FY NPS mission by reserve reporting unit code (RRUC)/MOS, and introduce the following FY prior service mission. The final meeting is the Reserve Mission Confirmation Conference that takes place each summer in Quantico, Virginia. The conference is led by the Director, Reserve Affairs. Its goal is to finalize the prior service mission and provide implementation guidance as well as any coordination necessary for the upcoming FY recruiting mission to include formally briefing MCRC and MARFORRES on new policies that affect accessions (e.g., bonuses, failure to promote policies, join credit policy).

1. SelRes Recruiting Missions

In general, RA manpower analysts develop SelRes accession and new prior service affiliation requirements based on historical trends and projected losses for the following fiscal year.¹³ This approach has gradually evolved as RA has become more sophisticated in its modeling. Recruiting plans now forecast losses at individual SMCR units so that recruiters will have known billets to fill.

Since FY09, the NPS/PS split has been approximately 60/40 and the recruiting missions have reached a fairly steady state. MCRC recruits roughly 4,100 prior service and 5,700 non-prior service (NPS) accessions per year. While the overall mission has reached a steady state, the SMCR officer recruiting mission has steadily risen. MCRC now accesses roughly 420 PS SMCR officers and 125 NPS SMCR officers per year.¹⁴

At the annual mission confirmation conference each summer, approximately 50% of reserve prior service recruiting missions are specified via quota serial numbers (QSN). QSNs link an individual manpower requirement to an RRUC, acceptable pay grades, and

¹³ Price, 21.

¹⁴ *Memo-01*, (Quantico, VA: U.S. Department of the Navy, 2012).

MOS.¹⁵ In order to allow flexibility to meet emerging requirements and unanticipated losses, the remaining prior service QSNs are left “open” and an RRUC and MOS is not assigned. These QSNs and the accession time-phasing requirements are then assigned to MCRC by the Deputy Commandant, Manpower & Reserve Affairs in a requirements document known as “Memo 01.”

2. Incentives

The majority of SMCR officers are eligible for the Inactive Duty Training (IDT) Travel, which “provides for reimbursement of actual expenses and mileage incurred during travel between a reserve member’s residence and their reserve training center (RTC) when travel is undertaken for the purpose of attending IDT.”¹⁶ The IDT Travel incentive is an important recruiting and retention tool because it allows Marines to defray travel costs (up to \$300 per round trip) to SMCR units that are 150 miles or more from their residence. Some of these units are geographically isolated and it is difficult to recruit Marines to serve there. SMCR company grade officers are also eligible for an Officer Affiliation Bonus (OAB). For FY13, the bonus is generally \$10,000, targeted directly at company grade officers and pilots; although, for some hard-to-fill billets, the bonus amount has been increased to \$20,000,¹⁷ based on authorization recently approved in the FY13 NDAA.¹⁸

E. CHAPTER SUMMARY

This chapter provides a brief overview of the Marine Corps Reserve Component with a special emphasis on the Selected Marine Corps Reserve (SMCR). It is also important for the reader to have a basic understanding of the RC accession process and its incentives.

¹⁵ Price, 22.

¹⁶ MARADMIN 045/13.

¹⁷ MARADMIN 065/13.

¹⁸ S. 3254--112th Congress: National Defense Authorization Act for Fiscal Year 2013. January 10, 2013. <http://www.govtrack.us/congress/bills/112/s3254>

III. LITERATURE REVIEW

A. INTRODUCTION

In the nineteenth century, Andrey Markov, a Russian mathematician, introduced the concept of chained events and what is now commonly called the Markov model.¹⁹ There is a lot of academic and scientific literature regarding Markov models. Markov models have a wide array of uses in mathematics, operations research, and manpower planning. Markov models are now common to manpower planning because they are an accurate and mathematical way of modeling the behavior of a system. Bartholomew et al. explained that:

There are two features of most manpower planning problems which render them suitable for statistical treatment. The first is the concern with aggregates. Manpower planning, unlike individual career planning, is concerned with numbers, that is, with having the right numbers in the right places at the right time. The second feature of manpower planning which calls for statistical expertise is the fact of uncertainty. This arises both from the uncertainty inherent in the social and economic environment in which the organization operates and from the unpredictability of human behavior.²⁰

Literature regarding Markov Models and military manpower is sparse. More specifically, literature involving the Marine Corps Reserve Component (RC) is much more limited. It is important to research not only Markov models as they relate to the military, but also recent Marine Corps RC studies that address continuation rates and attrition. Since my model is predictive in nature, it should be able to survive different military recruiting and retention environments. Recently, Bruce Erhardt built an RC Markov model that determines the continuation rates for prior service and non-prior service enlisted population in the Selected Marine Corps Reserve (SMCR). However, there are studies that employ Markov models to resolve manpower planning problems.

¹⁹ Van Q. Nguyen, "Analysis of the U.S. Marine Corps' Steady State Markov Model for Forecasting Annual First-Term Enlisted Classification Requirements," 5.

²⁰ D. J. Bartholomew, A. F. Forbes, and S. I. McClean. *Statistical Techniques for Manpower Planning*. Chichester, England: John Wiley & Sons, 1991.

B. NON-MILITARY MANPOWER STUDIES USING MARKOV MODELS

Three major studies address Markov models and manpower. These studies lay the foundation for military manpower. They are: “Statistical Techniques for Manpower Planning” by D. J. Bartholomew, “Attainable and Maintainable structures in Markov Manpower Systems with Pressure in the Grades” by A. G. Kalamatianou, and “The Validity of the Markov Chain Model for a Class of the Civil Service” by Pauline Sales.

Perhaps the most relevant of the three is the Sales study because it models civil service grade flows. Civil service systems are similar to the Marine Corps RC because both have “mutually exclusive and exhaustive classes defined in terms of some variable of interest, in this case, grade.”²¹ In this study, Sales explains that using a Markov model provides a more concise prediction of future changes in the grade structure of the scientific civil service. She also explains “each grade consisted of people with 5 different scientific functions (e.g., physicists, chemists, etc.).” This is relevant to the research because it is important to decide whether to build a model that incorporates military occupational specialty (MOS). Sales’s model is accurate despite the fact that scientific functions were not separated from grade. This meant that MOS would probably not need to be incorporated into the model.

Kalamatianou’s work is also relevant to manpower planning. The manpower structure she describes in her article is very similar to hierarchically graded manpower structures in the military. This article addresses recruitment and promotion pressure in grades that are obviously important to any military manpower model. Specifically, she stated that “high values of pressure would tend to make the system unstable with respect to promotions. A high proportion of unpromoted employees could have a serious effect on the efficiency of the organization for several reasons.”²² Her research is also relevant because the SMCR structure size is, for all intents and purposes, fixed. Hence, a

²¹ Pauline Sales, “The Validity of the Markov Chain Model for a Class of the Civil Service.” *Journal of the Royal Statistical Society* 20, no. 1 (March 1971): 85.

²² A. G. Kalamatianou, “Attainable and Maintainable Structures in Markov Manpower Systems with Pressure in the Grades.” *The Journal of the Operational Research Society* 38, no. 2 (February 1987): 183.

recruitment vector should be able to sustain the RC officer procurement system. Kalamatianou explained that:

It is useful to notice here that, because maintainable structures like those considered in this paper have their total size fixed ... This means that these structures can always be attained from any initial structure if we repeatedly use the recruitment vectors which maintain them.²³

Bartholomew addressed a number of salient issues in his study. He begins his study with a concise yet informative description of manpower planning. He writes: “At the level of the firm, manpower planning deals with problems of recruitment, wastage, retention, promotion and transfer of people within the firm and in relation to its environment.”²⁴ Bartholomew focused his essay on the wastage (i.e., attrition) component in a manpower system. He further explained that the uncertainties in manpower planning require that an analysis of manpower problems must involve a stochastic, or probability-based, approach. Currently, the RC officer manpower model is not a stochastic model and it does not use any probabilities to model flows and stocks.

The recruitment vector is used with either a fixed recruiting or fixed inventory model. The SMCR is better suited to a fixed inventory model because it is limited by its end strength cap of 39,600 Marines. More specifically, the officer population is constrained at the higher officer pay grades. The Reserve Officer Personnel Management Act (ROPMA) provides authorized strengths for active and reserve officers in pay grades O-4 to O-10.²⁵

C. DEVELOPMENT OF A MARKOV MODEL FOR FORECASTING CONTINUATION RATES FOR ENLISTED PRIOR SERVICE AND NON-PRIOR SERVICE PERSONNEL IN THE SELECTIVE MARINE CORPS RESERVE (SMCR)

Bruce Erhardt Jr. developed a Markov model to determine the continuation rates for prior service and non-prior service enlisted population in the Selected Marine Corps

²³ Kalamatianou, 189.

²⁴ D. J. Bartholomew, “The Statistical Approach to Manpower Planning.” *Journal of the Royal Statistical Society* 20, no. 1 (March 1971): 3.

²⁵ Public Law 103-337.

Reserve (SMCR). The results of his model validation indicate that using annual aggregate monthly transition rates will not satisfy the stationarity assumption required of Markov models. His model failed the stationarity assumption because attrition behaviors are likely cyclical. A large percentage (45-50%) of Marines join during the June-September (JJAS) months. He concluded that “the attrition behaviors are seasonal for both enlisted populations leading to numerous states being non-stationary in part due to their correlation with seasonality.”²⁶ He recommended developing and employing models with unique transition rates for each month.

D. ANALYSIS OF THE U.S. MARINE CORPS’ STEADY STATE MARKOV MODEL FOR FORECASTING ANNUAL FIRST-TERM ENLISTED CLASSIFICATION REQUIREMENTS

Van Nguyen’s 1997 study attempts to validate the Markov model used by manpower planners at Headquarters Marine Corps (MPP-23) to forecast the annual first-term enlisted classification requirements of new active component recruits. The MPP-23 model applied annual transition rates across time to an initial inventory to forecast the future inventory. To account for accessions, additional inventory was added to the system for each application of transition rates. In his analysis, Nguyen found that first-year continuation rates were underestimated across all primary military occupational specialties (PMOS) and rounding errors resulted in imprecise classification estimates.²⁷

E. FORECASTING RETENTION IN THE UNITED STATES MARINE CORPS RESERVE

The data analysis results for factors influencing retention are mixed. Joseph Schumacher studied the relationships between mobilization, deployment lengths, and home of record unemployment on reservist retention. His study was important because transition probabilities are likely affected by major events such as deployments and the frequency of mobilization. His research showed that “the effects of being called to active

²⁶ Bruce J. Erhardt Jr., “Development of a Markov Model for Forecasting Continuation Rates for Enlisted Prior Service and Non-Prior Service Personnel in the Selective Marine Corps Reserve (SMCR),” (Master’s thesis, Naval Postgraduate School, 2012), 39.

²⁷ Nguyen, 37.

service are shown to have a positive effect on retention in the reserves. Similarly, serving in the SMCR and Stand-by Reserves are both shown in the model to have a positive effect on reserve retention.”²⁸

Joseph Schumacher also found that the home of record unemployment rate had a negative effect on retention as well. This is counterintuitive since the RC offers a pay check and health insurance. The negative effect is compounded with more deployments. This seems important to recognize when looking at individual areas of the country during a recession and reserve mobilizations. Since most parts of the country are negatively affected during a recession, there is a high likelihood that reserve mobilizations would lead to lower retention and continuation rates. This would need to be factored into any model dealing with the reserves, even if its effect on officer continuation rates is unclear at this point.

Joseph Lizarraga provided a more detailed and updated look at retention and continuation rates by mobilization length and when they mobilized – pre-9/11, overlap 9/11 and post-9/11. He identified the effects of mobilization and its influence on Marine Corps Reserve NPS personnel continuation rates. Lizarraga found that overseas deployments do not negatively impact continuation if initial expectations of deployment are clear.²⁹ In other words, Marines who joined after 9/11 were more likely to continue than Marines who joined prior to 9/11.

Price et al. developed a Markov model to predict grade strengths in the Reserve Active Status List (RASL) for use in optimizing promotion zones and opportunities.³⁰ While this research was helpful, it differed quite a bit from this thesis. Our research focused specifically on SMCR unit vice RASL officers. This is important to note since the RASL behaves very differently than SMCR units. For instance, a loss from an SMCR

²⁸ Joseph F. Schumacher, “Forecasting Retention in the United States Marine Corps Reserve,” (Master’s thesis, Naval Postgraduate School, 2012), 40.

²⁹ Joseph M. Lizarraga, “Patterns of Marine Corps Reserve Continuation Behavior: Pre- and Post-9/11,” (Master’s thesis, Naval Postgraduate School, 2011), 126.

³⁰ Jonathan Price, Kyle Hahn, Jeremy McLaughlin, and Rachel T. Silvestrini. “Optimizing Promotion Opportunity and In-Zone Range for the Unrestricted Marine Corps Reserve Officer Population,” 25.

unit to the IRR in our model is not considered a loss in the subject promotion model. Also, our research focused on NPS and PS populations and behavior vice in-grade and promotion behavior, whereas the promotion model focuses on AC-RC transitions. Our model specifically incorporates PSR and NPS recruiting missions dictated in Memo-01 to SMCR units.

F. CHAPTER SUMMARY

Bartholomew, Kalamatiou, and Sales show how the Markov model can be applied to manpower systems. Erhardt's thesis was the first to apply Markov model theory to the SelRes. His methodology is sound but his model was not able to account for seasonality and it did not incorporate monthly transition probabilities. Any model of SMCR behavior should probably account for seasonality and use unique monthly transition rates. The Schumacher and Lizarraga theses provide manpower planners with reasons to be cautious of their retention and continuation models during wartime. Specifically, Marines will stay or leave the SelRes at different rates during a major conflict. This is important to manpower planners because the probability estimates will almost certainly lag what is actually happening and cause poor biased planning estimates.

IV. DATA AND METHODOLOGY

A. INTRODUCTION

This chapter presents the data used in the model and the methodology used to forecast. It discusses the data collection process, and provides descriptions of variables used and how they were incorporated into the model.

B. DATA SOURCES

1. Reserve Affairs Personnel Plans, Policy, and Programming (RAP-2)

RAP-2 provided the data for use in this study by gathering data from the Marine Corps Total Force Data Warehouse (TFDW). All personal identifiable information (PII) was sanitized from all data used in this study.

a. Total Force Data Warehouse (TFDW)

The data used in this study was drawn from the Marine Corps TFDW system. The Manpower Information (MI) Division at Manpower and Reserve Affairs (M&RA) provided access to the stored records for this study. The TFDW is a Marine Corps database containing numerous data fields. They include but are not limited to: financial, service, and demographic information for all Marine Corps personnel (enlisted, officer, active, and reserve). TFDW receives its data each month from the Marine Corps Total Force System (MCTFS). The TFDW is an accumulation of data taken on the last day of every month. For this thesis, we used 18 data fields to construct and validate the Markov model. The data represents more than 298,000 monthly person observations from the period of September 30, 1998 (sequence 115) to October 31, 2012 (sequence 284).

2. Descriptive Variables

The following descriptive variables were pulled from the TFDW for the Markov models. The data from TFDW consisted of 18 variables. We then input them into STATA and SAS to merge, append, code, and clean. The quantitatively derived transition probabilities and on-hand quantities were then exported to Microsoft Excel and

incorporated into the Markov models. Most of the variable definitions were taken from the Marine Corps Reserve Administrative Management Manual (MCRAMM).

a. *Present Grade Code (grade)*

Present grade code is the Marine's pay grade at that particular sequence.

This thesis focuses on the SMCR officer population; there is no enlisted data.

b. *Mandatory Drill Participation Stop Date (MDSD)*

The MDSD is the date that a non-prior service RC officer/enlisted Marine has met his or her mandatory drilling obligation with an SMCR unit. This minimum period of obligation is contractually binding and it is determined based on the member's initial accession program agreement.³¹ Marines who incur an additional drilling obligation due to attendance at MOS retraining³² or acceptance of an affiliation bonus³³ are also provided a mandatory drilling obligation in the Marine Corps Total Force System (MCTFS).

c. *Pay Entry Base Date (PEBD)*

The constructed date that establishes the beginning of a member's creditable military service for longevity increases to basic pay and other items of military compensation. The reported date may have been adjusted for breaks in service.

d. *Total Satisfactory Years (sat_yrs)*

A reservist must earn a minimum of 50 points per anniversary year and serve a full 365/366 day period to complete a qualifying year for retirement purposes.³⁴

³¹ MCO 1001R.1K, 2-2.

³² MARADMIN 192/12.

³³ MARADMIN 230/12.

³⁴ MCO 1001R.1K, 9-21.

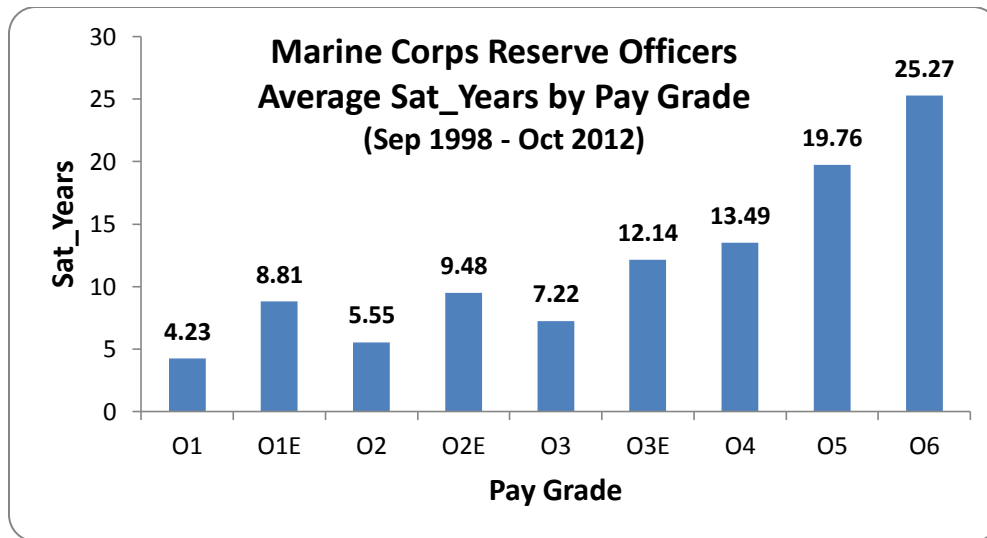


Figure 5. Marine Corps Reserve Officers Average Satisfactory Years by Pay Grade

e. Anniversary Date (annv_date)

Every reservist has a unique anniversary date and the anniversary year periods are calculated from this anniversary date. This date is established by the date the member entered into active duty or into an active status in the RC.

f. Reserve Component Code (rcompcode)

The reserve component code is a two-character code (e.g., KA, B5) that indicates the Marine's reserve component category or the Marine's contract status.

g. Reserve Reporting Unit Code (rruc)

The reserve reporting unit code is a five digit code that indicates the Marine's current unit (e.g., 88806).

h. Years of Commissioned Service (ycs)

This is the total number of years that the Marine has served as an officer.

i. Armed Forces Active Duty Base Date (afadbd)

AFADBD is the constructed date that establishes the beginning of a

Marine's creditable active military service. The reported date may have been adjusted for breaks in service and lost time.

j. Date Accepted First Commission (dafc)

This is the date the officer first accepted a commission in the U.S. Marine Corps. For missing values, the DAFC was constructed by using DOR as a baseline. Then, the number of days that it takes for a typical Marine officer to be promoted to a specific grade was subtracted from the DOR.

k. Satisfactory Months (sat_months)

This is a constructed variable. Sat_months is derived by “multiplying total satisfactory year by 12 months and then adding the result of one year (365 days) minus the sum of the anniversary date minus the sequence date, divided by one month (30.5 days) to provide a numerical unit to calculate PS Marines time in the reserve.”³⁵

$$Months_{Sat} = 12 \times Years_{Sat} + \frac{365 - (Annv_{date} - Seq_{date})}{30.5}$$

l. Source of Entry (soe)

SOE is the code used to identify how a Marine officer accessed into the Marine Corps. For this study, it was used to separate the NPS population (i.e., Reserve Officer Commissioning Program Marine officers) from the PS population Marine Officers (i.e., prior AC).

m. Fiscal Year (fy)

Dummy variables for each fiscal year were created by importing the

³⁵ Erhardt, 25.

appropriate sequences from TFDW and merging them into STATA. This thesis used sequences 115 through 284. Table 2 shows the sequence dates from FY98 to FY13.

	Sequences by FY											
	October	November	December	January	February	March	April	May	June	July	August	September
FY98	104	105	106	107	108	109	110	111	112	113	114	115
FY99	116	117	118	119	120	121	122	123	124	125	126	127
FY00	128	129	130	131	132	133	134	135	136	137	138	139
FY01	140	141	142	143	144	145	146	147	148	149	150	151
FY02	152	153	154	155	156	157	158	159	160	161	162	163
FY03	164	165	166	167	168	169	170	171	172	173	174	175
FY04	176	177	178	179	180	181	182	183	184	185	186	187
FY05	188	189	190	191	192	193	194	195	196	197	198	199
FY06	200	201	202	203	204	205	206	207	208	209	210	211
FY07	212	213	214	215	216	217	218	219	220	221	222	223
FY08	224	225	226	227	228	229	230	231	232	233	234	235
FY09	236	237	238	239	240	241	242	243	244	245	246	247
FY10	248	249	250	251	252	253	254	255	256	257	258	259
FY11	260	261	262	263	264	265	266	267	268	269	270	271
FY12	272	273	274	275	276	277	278	279	280	281	282	283
FY13	284	285	286	287	288	289	290	291	292	293	294	295

Table 2. Sequences by FY and Month

C. DESCRIPTIVE STATISTICS

Our sample size includes 298,906 observations. The observations consist of Marine Corps Reserve officers in the pay grades O-1 to O-6 (Figure 6).

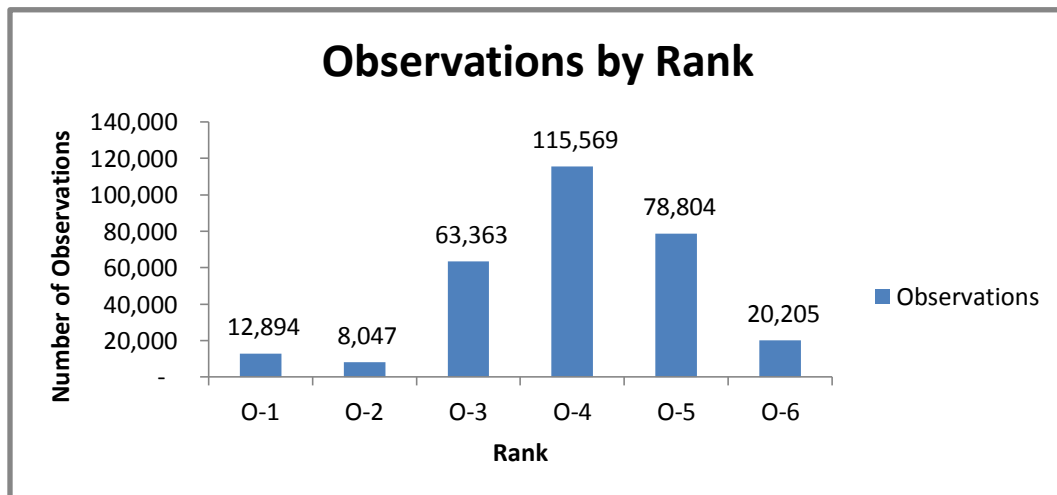


Figure 6. Observations by Rank

D. MARKOV MODEL THEORY

A Markov chain is a probabilistic (stochastic) model for describing the behavior of a system. The Markov model, similar to other manpower models, mathematically describes how changes occur in a personnel system. Unlike other manpower models though, the Markov model does not consider variables such as demographic trends or unemployment rates.³⁶ There are three basic assumptions in the Markov chain:

- The system consists of finite states.
- The Markovian Property: the probability that the system will transition to a following state depends only upon the current state.
- Stationary transition probabilities: given that an element of the system is in state i one period, then it will be in state j the next period with probability p_{ij} which is referred to as the transition probability from state i to j .

For purposes of this thesis, we are interested in constructing a fixed inventory model. In a fixed inventory model, the Markov process determines the number of personnel who must be accessed to meet the legislative end strength of the Marine Corps Reserve.³⁷

E. FIXED INVENTORY MODEL

The Marine Corps Reserve manpower model is based on stocks and flows.³⁸ Stocks are the distribution of officers in every rank and the total population of reserve officers. Flows are the transitions to the next state. Within this system are two types of flows of equal importance, flows into the system (recruitment) and flows between the various parts of the system—promotions, transfers, and wastages.³⁹ A fixed inventory model allows manpower planners the ability to perform sensitivity analysis on the various inputs to the model. Furthermore, the fixed inventory model uses transition probabilities,

³⁶ Jeffrey K. Sapp, "A Calculator Adaptation of the Markov Chain Model for Manpower Analysis," 12.

³⁷ R. Gillard, "Steps Towards Determining the Right Number of Dental Recruits the Navy Should Access to Meet the Projected Targets for Navy Dental Corps Officers," 21.

³⁸ Erhardt, 27.

³⁹ D. J. Bartholomew, "The Statistical Approach to Manpower Planning." *Journal of the Royal Statistical Society* 20, no. 1 (March 1971): 14.

an inventory vector, and an accession (or recruiting) vector to estimate a number of manpower outputs.

1. Methodology

a. Conceptual Model

The Markov model for this thesis constructs the flow of personnel through the manpower system. It consists of a transition matrix, an inventory vector, and a recruitment vector. The model calculates the monthly officer strength by identifying the number of Marines in the system at each state (satisfactory months) and how likely they are to continue to the next state. Personnel can flow through the system only by advancing to the next state or by leaving the system (wastage/attrition). Figure 7, adopted from Erhardt's model, depicts the system from zero satisfactory months to 300 satisfactory months.⁴⁰

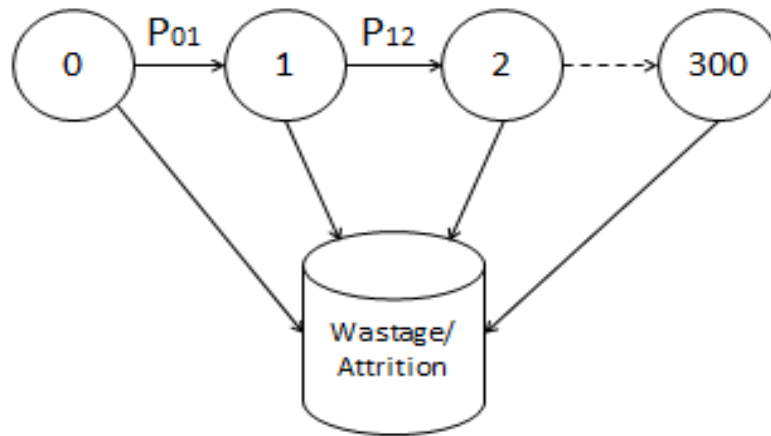


Figure 7. Conceptual Markov Model

⁴⁰ Erhardt, 28.

Figure 7 is a truncated model of Selected Marine Corps Reserve (SMCR) officer manpower flows. The system progresses from zero months to 300 satisfactory months (or 25 years). P_{01} is the probability that a Marine officer with zero months of service will flow to one month of service. If an officer leaves the system for any reason, he or she flows into the wastage/ attrition bin.

b. Transition Matrix

The first step in building a fixed inventory model is the transition matrix. A transition matrix shows the future and present states and the conditional probabilities that result from flowing from one state to another state.

c. Fixed Inventory Equation

The fixed inventory equation is used to predict stock sizes in the different categories while controlling the number of people recruited during the forecasted period of time.⁴¹

$$\mathbf{n}(t) = \mathbf{n}(t-1) \cdot \mathbf{P} + R(t)\mathbf{r}$$

Elements of the fixed inventory equation are as follows.

- $\mathbf{n}(t)$: $\mathbf{n}(t)$ is the inventory vector at time t . Time is labeled in discrete increments, such as $t = 0, 1, 2, 3$. For this study, time steps are one month in duration.
- $\mathbf{n}(t-1)$: $\mathbf{n}(t-1)$ is the inventory vector at the previous time step. When $t=1$, $\mathbf{n}(0)$ represents the initial inventory vector.
- \mathbf{P} : is the matrix of transition probabilities. The transition probability p_{ij} is the probability an element (i.e., officer) will transition from i to j in one time step.
- $R(t)$: is the number of Marine officers accessed into the system during time (t) . It is important to understand that prior AC and non-prior AC accessions are sourced from different populations and probably behave differently.
- \mathbf{r} : is the recruitment vector that determines the proportion of total recruits distributed among each state. For example, if $\mathbf{r} = (.50, .50, 0, 0)$, then 50% of the new personnel recruited will enter category one, 50% will enter category two, and 0% will enter category three or category four.

⁴¹ Erhardt, 29.

F. LIMITATIONS OF THE MODELS

The primary limitation with both models is the number of observations per state. Since there are 300 states, many of the states have 10 or fewer observations. This presents statistical significance problems and high variance in the rates. For example, if there are three O-1s with zero satisfactory months of service and one of them attrited, the model will generate a continuation rate (p_{ij}) of 0.667. Obviously, that is far too low because O-1s are contractually obligated and they attrite at a very low rate.

This problem is particularly acute with the NPS population since it is so small. There are less than 450 RC officers that have been commissioned via the ROCP. They currently populate less than 50% of the 300 states that comprise the model. This makes modeling the NPS population very difficult in all the models since the population has so few observations across only 140 months of service.

Lastly, some Prior AC officers now have mandatory drill stop dates because they accepted MOS retraining or an affiliation bonus. This will probably change continuation behavior in the model. We were unable to model this due to the recency of the procedural change.

G. SUMMARY

This chapter's goal is to provide the data fields, basic descriptive statistics for the data, and a methodology for how to construct a fixed inventory Markov model. This Markov model will be used as a tool for accession and end strength planning for the Marine Corps Reserve Prior RC (non-prior service) and Prior AC (prior service) officer populations.

THIS PAGE INTENTIONALLY LEFT BLANK

V. MODEL IMPLEMENTATION AND VALIDATION

This chapter outlines the implementation of the Marine Corps Reserve Officer PS (Prior Active Component) and the NPS (Prior Reserve Component) officer population models in Excel. It also assesses the validity of the models. The validation process uses data from FY10 through FY12. Two models were tested.⁴² The first was a model using 300 satisfactory months as states and an aggregate monthly transition rate. The second model used 300 satisfactory months and unique monthly transition rates.

A. NPS AND PS EXCEL AGGREGATE MONTHLY RATE MODELS

Each model has its own Excel workbook. The workbook has several tabs that feed into the Markov model to complete the calculations. The workbook sheets contain continuation rates, obligor growth, and on hand strength that provide inputs to each model. Figure 8 shows projected PS officer inventories by satisfactory months (sat_months) from December 2011 to September 2012.

	actual 30 September 2011		Transition													
Month of Service	n(0) On Hand			FY13												
0	1		# Sat Months	31-Oct-11	30-Nov-11	31-Dec-11	31-Jan-12	29-Feb-12	31-Mar-12	30-Apr-12	31-May-12	30-Jun-12	Jul-12	31-Aug-12	30-Sep-12	
1			0	0	0	0	0	0	0	0	0	0	0	0	0	
2			1	1	0	0	0	0	0	0	0	0	0	0	0	
3			2	0	1	0	0	0	0	0	0	0	0	0	0	
4	1		3	0	0	1	0	0	0	0	0	0	0	0	0	
5	2		4	0	0	0	1	0	0	0	0	0	0	0	0	
6	1		5	1	0	0	0	1	0	0	0	0	0	0	0	
7	3		6	2	1	0	0	0	1	0	0	0	0	0	0	
8			7	1	2	1	0	0	0	1	0	0	0	0	0	
9			8	3	1	2	1	0	0	0	1	0	0	0	0	
10			9	0	3	1	2	1	0	0	0	1	0	0	0	
11			10	0	0	3	1	2	1	0	0	0	1	0	0	
12	2		11	0	0	0	3	1	2	1	0	0	0	1	0	
13	3		12	0	0	0	0	3	1	2	1	0	0	0	1	
14			13	2	0	0	0	0	3	1	2	1	0	0	0	
15			14	3	2	0	0	0	0	3	1	2	1	0	0	
16			15	0	3	2	0	0	0	0	3	1	2	1	0	
17			16	0	0	3	2	0	0	0	0	3	1	2	1	
18			17	0	0	0	3	2	0	0	0	0	3	1	2	
19			18	0	0	0	0	3	2	0	0	0	0	3	1	
20			19	0	0	0	0	0	3	2	0	0	0	0	2	

Figure 8. Aggregate Monthly Rate Models Main Tab

⁴² We did not validate the Prior RC aggregate model because it had too few observations across only 140 states.

1. Main Tab

The main tab (Figure 9) incorporates all the data from the corresponding tabs and places the data into the fixed inventory formula. This worksheet displays the transition matrix from n_0 to n_{300} . It also shows the inventory vectors, satisfactory months and on-hand numbers. The following tabs supply the main tab with pertinent data used in the formula.

		Transition											
	n(0)												
Sat_Months	On Hand		0	1	2	3	4	5	6	7	8	9	10
0	32	0	0.0000	0.9932									
1	0	1	0.0000		0.9856								
2	1	2	0.0000			0.9914							
3	1	3	0.0000				0.9957						
4	46	4	0.0000					0.9874					
5	0	5	0.0000						0.9777				
6	0	6	0.0000							0.9783			
7	0	7	0.0000								0.9956		
8	0	8	0.0000									1.0000	
9	44	9	0.0000										0.9847
10	0	10	0.0000										
11	0	11	0.0000										
12	36	12	0.0000										
13	0	13	0.0000										
14	1	14	0.0000										
15	1	15	0.0000										
16	22	16	0.0000										
17	0	17	0.0000										
18	0	18	0.0000										
19	1	19	0.0000										
20	0	20	0.0000										
21	33	21	0.0000										
22	3	22	0.0000										
23	0	23	0.0000										
24	35	24	0.0000										
25	0	25	0.0000										
26	1	26	0.0000										
27	0	27	0.0000										
28	31	28	0.0000										
29	0	29	0.0000										
30	2	30	0.0000										
31	2	31	0.0000										
32	0	32	0.0000										
33	36	33	0.0000										
34	1	34	0.0000										

Figure 9. Transition Matrix and Inventory Vectors

2. Attrition_K4 Tab

This tab contains the satisfactory months of service and continuation rates for PS or NPS SMCR Marine officers, model dependent.

3. Growth Tabs

This tab shows the planned monthly SMCR officer accessions (i.e., planned monthly OCS graduations) for the NPS model and the planned monthly SMCR officer PS (or NPS) joins multiplied by the PS (or NPS) officer distribution array and PS (or NPS) join ratio (i.e., prior AC (or NPS) joins/total PSR officer joins).

4. Growth Rate Tabs

This tab contains the distribution rates necessary to determine the growth vectors in the aforementioned tab.

B. NPS MODEL WITH UNIQUE MONTHLY TRANSITION RATES

Based on Erhardt's research, a model based on a single aggregate monthly transition rate is likely to fail the stationary transition rates assumption. Figure 10 shows projected NPS officer inventories by satisfactory months (sat_months) from October 2011 to September 2012.

	FY12											
# of Months	31-Oct-11	30-Nov-11	31-Dec-11	31-Jan-12	29-Feb-12	31-Mar-12	30-Apr-12	31-May-12	30-Jun-12	Jul-12	31-Aug-12	30-Sep-12
0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	1	0	0	0	0	0	0	0	0	0	0	0
6	2	1	0	0	0	0	0	0	0	0	0	0
7	1	2	1	0	0	0	0	0	0	0	0	0
8	3	1	2	1	0	0	0	0	0	0	0	0
9	0	3	1	1	1	0	0	0	0	0	0	0
10	0	0	3	1	1	1	0	0	0	0	0	0
11	0	0	0	2	1	1	1	0	0	0	0	0
12	0	0	0	0	2	1	1	1	0	0	0	0
13	2	0	0	0	0	2	1	1	1	0	0	0
14	3	2	0	0	0	0	2	1	1	1	0	0
15	0	3	2	0	0	0	0	2	1	1	1	0
16	0	0	3	1	0	0	0	0	2	1	1	1
17	0	0	0	1	1	0	0	0	0	2	1	1
18	0	0	0	0	1	1	0	0	0	0	2	1
19	0	0	0	0	0	1	1	0	0	0	0	2
20	0	0	0	0	0	0	1	1	0	0	0	0

Figure 10. Main Tab (300 states with unique monthly transition rates)

1. Monthly Transition Matrices

Figure 11 shows the transition matrix for October in its own separate tab (P_Oct). There are 12 separate tabs for each month of the year. The transition probabilities are calculated from the attrition input tab in Figure 12.

col	Transition												
2	0	1	2	3	4	5	6	7	8	9	10	11	12
0	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Figure 11. October Transition Matrix (P_Oct)

2. Attrition Input Tab

This tab contains the attrition and continuation rates for all 300 states in the model. This tab facilitates updates to the monthly probability tabs. To clarify, the continuation rate is simply calculated by $(1 - \text{attrition rate})$. So, a state that has an attrition rate of 0.07 has a corresponding continuation rate of 0.93. Figure 12 shows continuation rates for the first 12 states.

Sat_Months	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0	1	1	1	1	1	1	1	1	0.667	1	1	1
1	1	0.667	0.667	1	1	1	1	1	1	1	1	1
2	1	1	0.833	1	0.8	1	1	1	1	0.857	1	1
3	1	1	1	0.8	0.5	1	1	1	1	1	1	1
4	1	1	0.833	0.714	1	1	1	1	1	0.875	1	0.857
5	1	1	1	0.75	1	1	1	1	1	1	0.857	1
6	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	0.833	1	1	1	1	1	1	0.8	1	1
8	1	1	1	0.75	1	1	1	1	1	1	0.75	1
9	1	1	1	0.7	1	1	1	1	1	1	1	1
10	1	1	1	0.818	1	1	1	1	1	1	1	1
11	1	1	1	0.5	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	1

Figure 12. Attrition Input Tab (ContinuationRates)

3. Growth_K4 Tab

This tab shows the expected Prior AC accessions by satisfactory months served in the Marine Corps. These Prior AC Marine officers affiliate with an SMCR unit via a prior service recruiter (PSR).

Node	FY12												FY13											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
74 MOS	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0
75 MOS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
76 MOS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
77 MOS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
78 MOS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
79 MOS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
80 MOS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
81 MOS	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1
82 MOS	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1
83 MOS	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1
84 MOS	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1
85 MOS	2	1	1	2	1	1	1	1	1	1	1	1	2	1	1	2	1	1	1	1	1	1	1	1
86 MOS	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1
87 MOS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
88 MOS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
89 MOS	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
90 MOS	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1

Figure 13. Growth K4 Tab

C. MODEL VALIDATION

In order to adjudicate between the two models, we use both models to predict various managerially relevant aspects of the manpower system for FY11 and FY12. We use actual accession data pulled from TFDW and fed that data into the model. For the FY11 and FY12 unique monthly transition rate models, we use the attrition rates from the previous FY to forecast behavior. For the FY11 aggregate monthly rate models, we use the FY10 aggregate monthly transition rate. For the FY12 aggregate monthly rate model, we use a two-year FY10 and FY11 aggregate monthly transition rate.

Overall, one of the aggregate monthly rate model and both of the unique monthly transition rate models performed well enough to function as workable models. The models based on unique monthly transition rates are stationary since using one year of data in each validation guarantees stationarity.

1. FY11 Prior AC Aggregate Monthly Transition Rate Model

The FY11 aggregate monthly transition rate model has the highest degree of variance of all the models tested. The initial inventory was that for September 30, 2010. The transition rate is the aggregate transition rate constructed from the 12 months from FY10. The accessions used are the actual FY11 monthly accessions. Figure 15 shows the model performing well in the first half of FY11 and then poorly for the second half. The model has a mean absolute percentage error (MAPE) of 6.48%, which is very high. Most importantly, the final end strength projection is inaccurate (-6.76%). Since end strength projection is the primary goal of this thesis, this model should be considered invalid because it misses end strength by a significant amount. This model would also cause budget programming issues for much of the year since it underestimates the number of PS officers on hand.

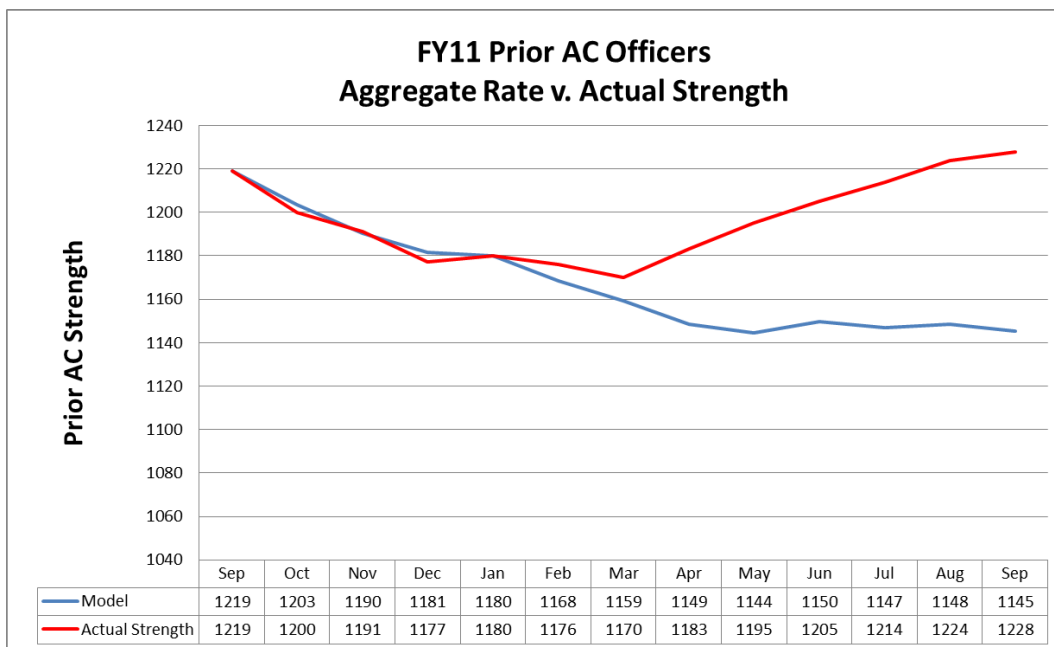


Figure 14. FY11 Aggregate Rate v. Actual Strength

2. FY11 Prior AC Unique Monthly Transition Rates Model

Figure 15 depicts the FY11 unique monthly transition rates model. The initial inventory was that for September 30, 2010. The transition rates are unique monthly rates

constructed from the 12 months of FY10. The accessions used are the actual FY11 monthly accessions. Overall, it is a well-behaved model that underestimates SMCR officer strength throughout most of FY11. The model has a MAPE of 3.77%, which is acceptable for planning purposes. The model underestimates end strength by 3.75%, but that is three percentage points better than the FY11 aggregate monthly transition rate model. Furthermore, the model is stationary and the final end strength projection is more accurate than the aggregate transition rate model. Given its relative accuracy, this model should be considered valid.

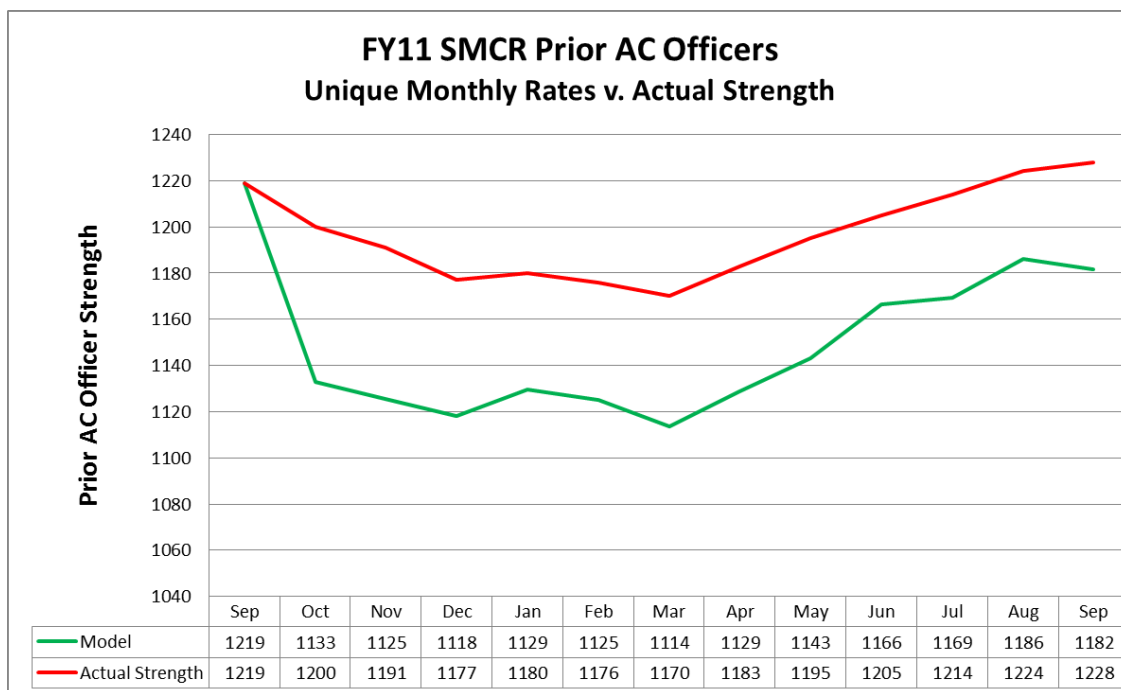


Figure 15. FY11 Unique Monthly Transition Rates v. Actual Strength

3. FY12 Prior AC Aggregate Monthly Transition Rate Model

The FY12 aggregate monthly transition rate model in Figure 16 shows a well-behaved model. The initial inventory was that for September 30, 2011. The transition rate is the aggregate transition rate constructed from the previous 24 months of FY10 and FY11. The accessions used are the actual FY11 monthly accessions. It performs well for nearly all of FY12 and it comes very close to predicting end strength. The model has a

MAPE of 0.95%, which is excellent. The model overestimates end strength by only 0.90%, which means it is exceptionally accurate. Overall, it is a valid model based on its overall behavior and accuracy.

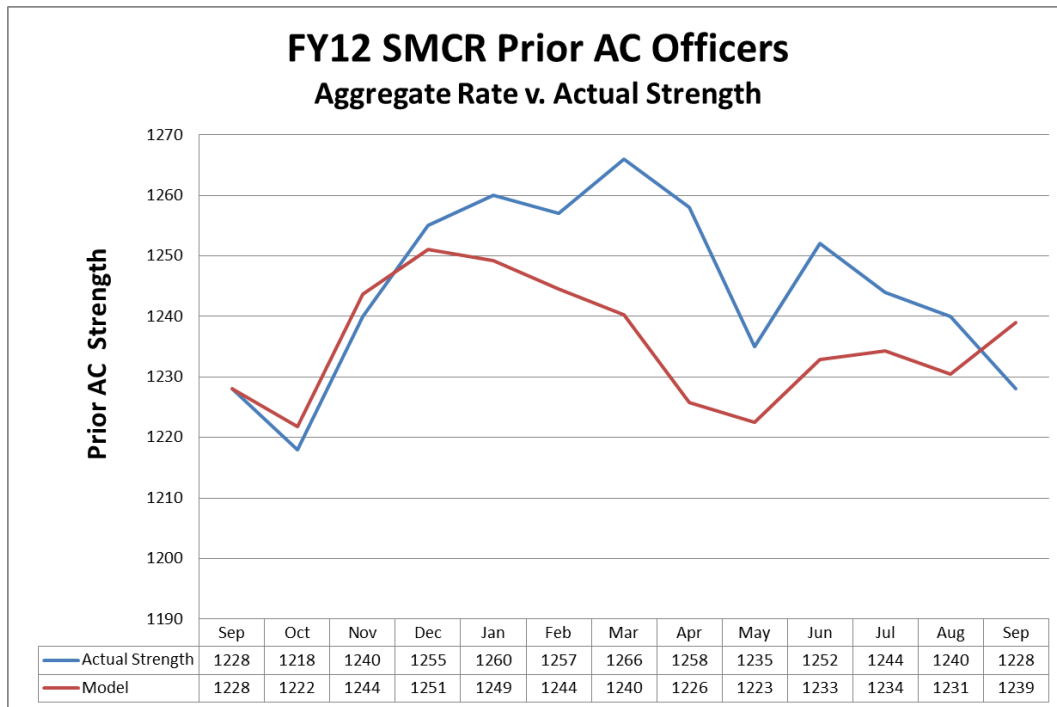


Figure 16. FY12 Aggregate Rate v. Actual Strength

4. FY12 Prior AC Unique Monthly Transition Rates Model

The FY12 unique monthly transition rates model had a very small variance throughout the model. The initial inventory was that for September 30, 2011. The transition rates are unique monthly rate constructed from the 12 months from FY11. The accessions used are the actual FY12 monthly accessions. Figure 17 shows a model that performs very well throughout the first half of FY12, but poorly in the second half. The model is stationary, but the final end strength projection is inaccurate. This was likely due to implementation of Marine Corps billet assignment policies during the second half of FY12 which artificially increased unit losses. This model's percent error is only 1.62%, which is very good. However, it overestimates end strength by 5.3%. Overall, this model is valid even if it somewhat overestimates end strength.

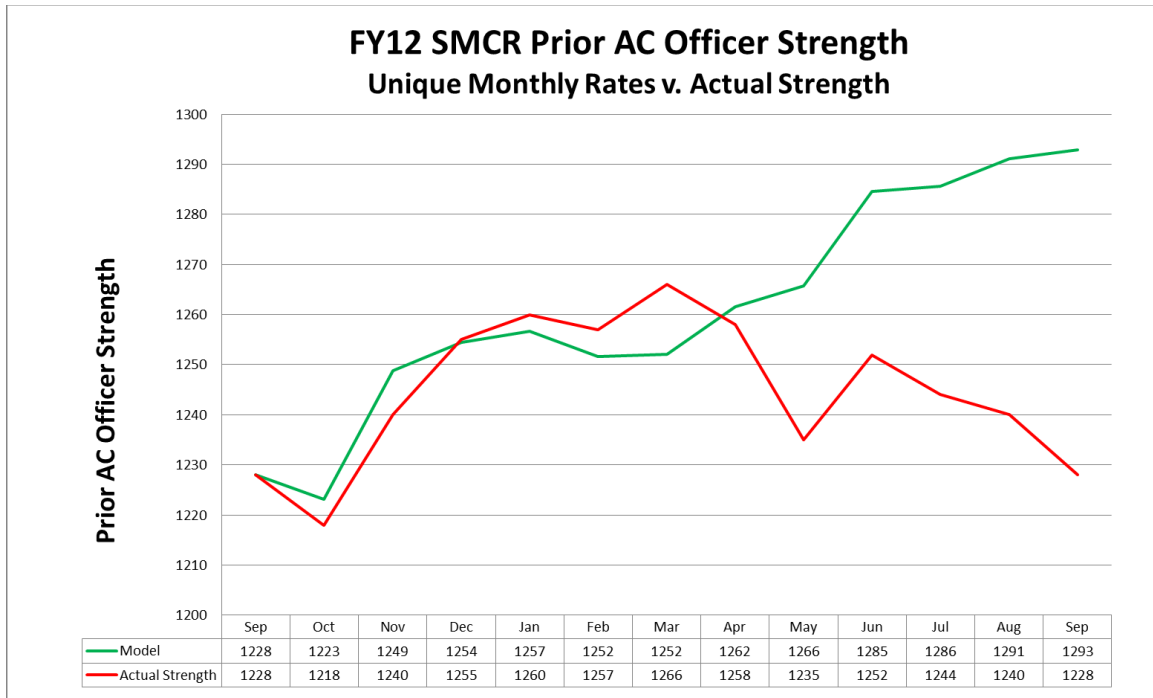


Figure 17. FY12 Unique Monthly Transition Rates v. Actual Strength

D. MODEL COMPARISONS

Table 3 summarizes the performance of the various models. The model average strength is simply the average of all 12 monthly predictions in the fiscal year. This is important because RA manpower and budget planners use average strength as a planning measure when developing budget estimates. Three of the models produce acceptable results; the FY11 Aggregate Rate model is the only one that does not. All four models perform better than the current RAP-2 models.

Model	Mean Absolute Percent Error (MAPE)	Model Average Strength	Actual Average Strength	Δ Model-Actual	Model End Strength Prediction	Actual End Strength	Δ Model-Actual
FY11 Aggregate Rate	6.48%	1170	1195	-25	1145	1228	-83
FY11 Unique Rates	3.77%	1143	1195	-52	1182	1228	-46
FY12 Aggregate Rate	0.95%	1236	1246	-10	1239	1228	11
FY12 Unique Rates	1.62%	1264	1246	18	1293	1228	65

Table 3. Model Comparison without Monthly Inventory Updates

Another way that RAP employs this model is to estimate the end of FY end-strength each month during the fiscal year. We employ both models and compare their performance along this margin as well. For example, suppose we wish to assess the performance of the aggregate model during FY11. We use same aggregate transition rates as above and we use the actual observed accessions as $R(t)$. For the October estimate of that year, we use the actual inventory from September 30, 2011. To obtain the November estimate of that year, we use the actual inventory from 1 November 2010 and estimate the inventory after 11 time steps, and so on. Figure 18 displays the results for FY11 while Figure 19 displays the results for FY12. Like the previous model comparison, no model is clearly better but the aggregate monthly rate models have a slight edge over the unique monthly transition rates in within year end strength prediction Table 4).

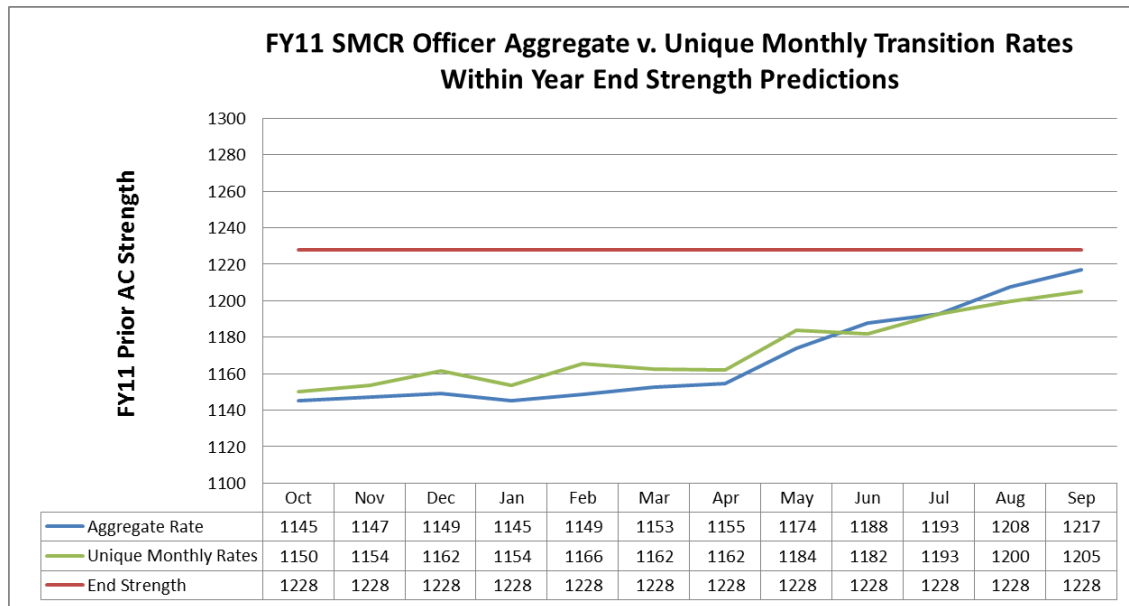


Figure 18. FY11 SMCR Officer Aggregate v. Unique Monthly Transition Rates
(within year end strength predictions)

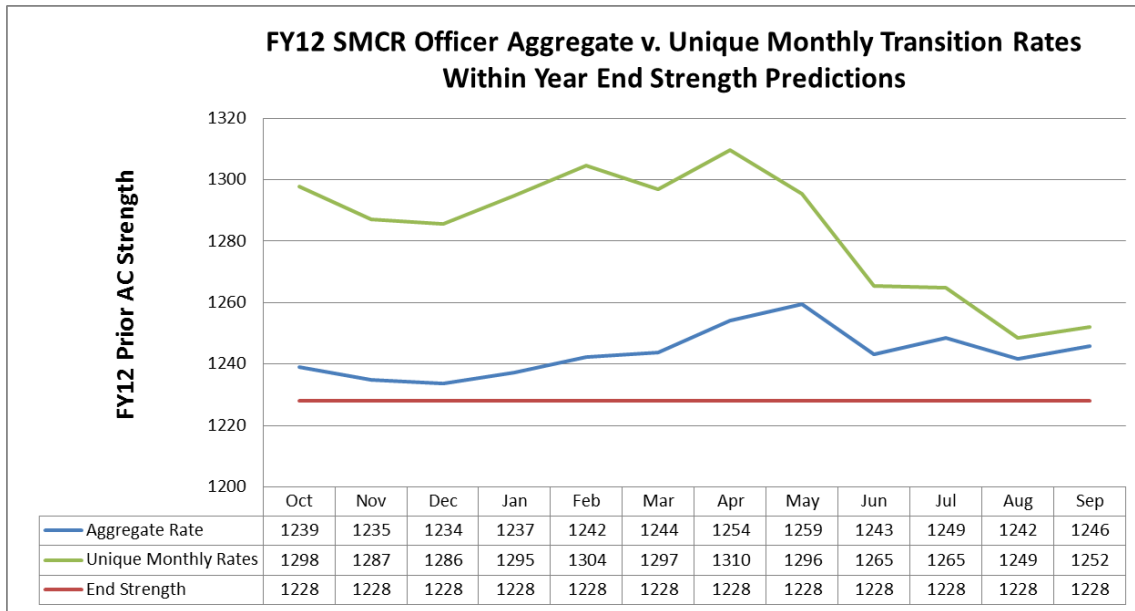


Figure 19. FY12 SMCR Officer Aggregate v. Unique Monthly Transition Rates
(within year end strength predictions)

Model	Mean Absolute Percent Error	Model End Strength Prediction	Actual End Strength	Δ Model - Actual
FY11 Aggregate Rate	4.85%	1217	1228	-11
FY11 Unique Rates	4.50%	1205	1228	-23
FY12 Aggregate Rate	1.27%	1246	1228	18
FY12 Unique Rates	4.53%	1252	1228	24

Table 4. Model Comparison with Monthly Inventory Updates

Manpower planning is not our sole concern. The Marine Corps uses these estimates to forecast in-year budget execution and the necessity for mid-year review of RPMC. Thus, the model results must also take into account cost. Inaccurate estimates can cost the Marine Corps money whether we overspend or underspend the RPMC account.

E. MODEL COMPARISON USING COST ESTIMATES

Given that the Marine Corps and the DoD are entering a period of budget austerity, accurate manpower projections are even more important now. In order to determine each model's cost estimate, we need to determine the composite rate for SMCR officers. SMCR officers fall into RPMC Pay Group A for budget purposes. Table 5 briefly explains the major Marine Corps Reserve pay groups.

Major Reserve Pay Groups		
Pay Group	Category	Description
A	SMCR Units	Pays for pay, allowances, and travel for Inactive Duty Training (IDT) including Additional Paid Drills (ATPs/RMPs/AFTPs/FHDs) and Annual Training (AT) including AT Travel and IDT Travel Reimbursement
B	IMA	Pays for pay, allowances, and travel for Inactive Duty Training (IDT) and Annual Training (AT)
F	Non-Prior Service Training	Pays for pay, allowances, and travel for all entry-level training
Q	Active Reserve (AR)	Pays for pay, allowances, and travel for AR personnel including Reserve Incentives (RC Bonuses)

Table 5. Reserve Personnel, Marine Corps Pay Groups⁴³

First, we use the SMCR officer Inactive Duty Training (IDT) composite rates for FY11 and FY12. We multiplied the difference between the model and the actual SMCR officer strength to arrive at an IDT cost difference (Table 6).

⁴³ *President's Budget FY12 RPMC Pie Chart*. Quantico, VA: U.S. Marine Corps, 2012.

	IDT Model Average Strength	IDT Actual Strength	IDT Officer Composite Rate	Δ Model- Actual	IDT Cost Difference
FY11 Aggregate Rate	1170	1195	\$18,060	-25	(\$451,500)
FY11 Unique Rates	1143	1195	\$18,060	-52	(\$939,120)
FY12 Aggregate Rate	1236	1246	\$18,588	-10	(\$185,880)
FY12 Unique Rates	1264	1246	\$18,588	18	\$334,584

Table 6. Inactive Duty Training (IDT) Estimated Costs per Model

Second, after determining IDT cost difference, we then calculate the composite rate for SMCR officer annual training (AT). Since most AT is performed in the summer months (June-August), we determined the average strength difference between the models and actual SMCR officer strengths during those months. We did this by averaging the SMCR officer actual and model strengths in the June – August months in FY11 and FY12 (Table 7). We then multiplied the difference by the FY11 and FY12 AT composite rates for SMCR officers and this equals the “AT Cost Difference.”

	AT Model Average Strength	AT Actual Strength	Δ Model- Actual	AT Composite Rate	AT Cost Difference
FY11 Aggregate Rate	1148	1214	-66	\$5,574	(\$367,884)
FY11 Unique Rates	1172	1214	-42	\$5,574	(\$234,108)
FY12 Aggregate Rate	1233	1245	-12	\$5,737	(\$68,844)
FY12 Unique Rates	1287	1245	42	\$5,737	\$240,954

Table 7. Annual Training (AT) Estimated Costs per Model

Last, we compare all the models by adding the IDT cost difference to the AT cost Difference (Table 8). The FY12 models are more accurate than the FY11 models. Also, neither the aggregate rate model nor the unique monthly rates model has a clear advantage, but the aggregate models have a slight edge in cost.

	IDT Cost Difference	AT Cost Difference	Total Cost Difference
FY11 Aggregate Rate	(\$451,500)	(\$367,884)	(\$819,384)
FY11 Unique Rates	(\$939,120)	(\$234,108)	(\$1,173,228)
FY12 Aggregate Rate	(\$185,880)	(\$68,844)	(\$254,724)
FY12 Unique Rates	\$334,584	\$240,954	\$575,538

Table 8. Summary of Costs per Model

F. FORECASTING CONTINUATION BEHAVIOR FOR PRIOR RC MARINES

The major challenge to modeling the Prior RC officer population is that there are so few officers who have accessed since FY06. With only 450 accessions, the data is sparse and a Markov model with 300 states does not produce useful results. This rules out the best method we have available to forecast continuation behavior for this population. Moreover, Prior RC officer observations drop significantly after 73 satisfactory months. The Prior AC population has much more data and it conforms well to a Markov model. Just to compare the two sets of rates through 73 satisfactory months, we placed both on a graph and ran a simple correlation. Figure 20 shows the attrition rates for Prior RC officers against the attrition rates for Prior AC officers. As a reminder, attrition rates are simply calculated by subtracting the continuation rate from one.

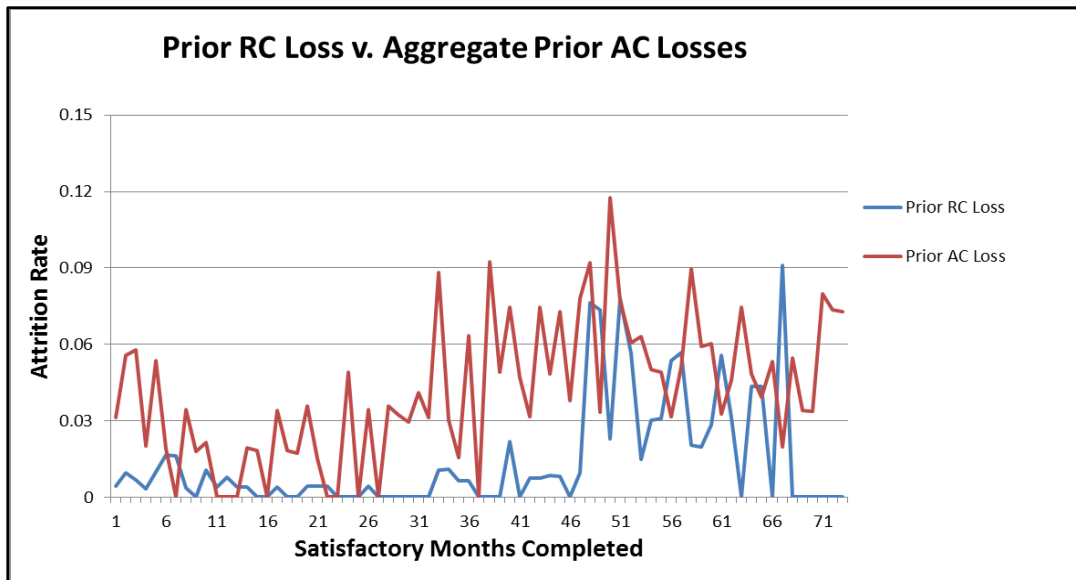


Figure 20. Prior RC Officer Attrition Rates v. Aggregate Prior AC Loss Rate

In the first 73 months, there is a small correlation between the two data sets (correlation = 0.216). Based on this, we cannot draw any reasonable inferences from the two populations yet. Also, there is very little data to surmise how the Prior RC population behaves beyond that point. We also cannot fit an autoregressive integrated moving average (ARIMA) model because the data is not a times series. The best a manpower planner can do at this point is to make an educated assumption as to how the Prior RC population will behave beyond the initial 73 months. More likely than not, the two populations will act very similarly after a certain point in time. This is because both Prior AC and Prior RC officers, after sufficient time in the RC, probably adopt the same attitudes and comfort level. This is clearly an area for further data collection and study.

G. SUMMARY

The validation results demonstrate that both the aggregate rate and unique monthly rate models are valid and could be used by RAP manpower planners. The FY12 models produced better results than the FY11 models in both cost estimates and percent error. Overall, there is not a clear difference between the unique monthly rates models and the aggregate monthly rate models. However, the aggregate monthly rate models performed slightly better than the unique monthly transition rate models with respect to

end strength prediction, average strength prediction, and cost. Despite the inherent problems in the aggregate monthly rate models, the FY12 aggregate monthly rate model performed the best of all the models. This is unexpected because an annual aggregate monthly transition rate cannot account for seasonality whereas unique monthly transition rates do account for that seasonality.

VI. CONCLUSION AND RECOMMENDATION

A. CONCLUSION

The purpose of this thesis is to develop a model to forecast end strength for Selected Marine Corps Reserve NPS and PS Marine officers. We built two separate models for the Prior Active Component (AC) officers and one for the Prior Reserve Component (RC) officers. For the Prior AC officers, we build one model with an aggregate monthly transition rate and one with unique monthly transition rates. We validate the unique monthly transition rate models by loading FY11 and then FY12 accession and the previous year's attrition data and then forecasted that fiscal year's end strength. Likewise, we validate the aggregate model by loading that fiscal year's accession data and an aggregate attrition rate and then simulating that fiscal year's end strength forecast. We do not validate the Prior RC officer model because it does not have enough observations per state and its data only populated roughly half of the states.

The Prior AC model validation and analysis show that an aggregate monthly rate and unique monthly transition rates produce similar results. Consistency and accuracy are important because budget planners and recruiting command rely on manpower estimates during the fiscal year. In fact, Programs and Resources (P&R), Marine Corps Recruiting Command, and Manpower & Reserve Affairs all rely on the most accurate manpower estimates to conduct programming, budgeting, mission planning and execution. Overall, the aggregate monthly rate models perform slightly better than the unique monthly transition rate models with respect to end strength prediction, average strength prediction, and cost. More importantly, all Prior AC models performed better than Reserve Affairs' current models.

Lastly, we are unable to validate the Prior RC officer model. Since there are so few observations, the transition rates are suspect because they have a very high variance. At this time, the best approach is to use the Markov model we constructed and continue to update it and validate it when the population matures. It is also worth exploring whether the number of states can be reduced from 300 satisfactory months to 30

satisfactory years. This would allow more observations per state and add confidence to both models.

B. RECOMMENDATIONS/FUTURE RESEARCH

This thesis constructs multiple models for forecasting officer SMCR officer end strength. We recommend that RAP-2 planners use both Prior AC models and the aggregate Prior RC in FY13 or FY14 to test how the models work in FY13. For planning purposes, we recommend that RAP-2 planners use a model with an aggregate monthly transition rate.

The following topics are recommended for future research.

- Analysis of behavior of Prior AC verses Prior RC Marine officers. We feel that this topic should be explored after another three or four fiscal years of data have been collected.
- Analysis of the aggregate Prior RC model after two fiscal years to determine whether it produces sound manpower estimates.
- A manpower model based on 30 satisfactory years. We believe this model will be the most accurate because the number of Marine officers in each state will be greater than the current 300 state models.
- A study that assesses the continuation behavior of SMCR officers who accept affiliation bonuses or MOS retraining. We recommend this for study in two to three years after the policy has matured.

LIST OF REFERENCES

- Bartholomew, D. J., A. F. Forbes, and S. I. McClean. *Statistical Techniques for Manpower Planning*. Chichester, England: John Wiley & Sons, 1991.
- Bartholomew, D. J. "The Statistical Approach to Manpower Planning." *Journal of the Royal Statistical Society* 20, no. 1 (March 1971): 3–26.
- Erhardt Jr., Bruce J. "Development of a Markov Model for Forecasting Continuation Rates for Enlisted Prior Service and Non-Prior Service Personnel in the Selective Marine Corps Reserve (SMCR)." Master's thesis, Naval Postgraduate School, 2012.
- Gillard, Richard. "Steps Towards Determining the Right Number of Dental Recruits the Navy Should Access to Meet the Projected Targets for Navy Dental Corps Officers." Master's thesis, Naval Postgraduate School, 2007.
- Kalamatianou, A. G. "Attainable and Maintainable Structures in Markov Manpower Systems with Pressure in the Grades." *The Journal of the Operational Research Society* 38, no. 2 (February 1987): 183–190.
- Lizarraga, Joseph M. "Patterns of Marine Corps Reserve Continuation Behavior: Pre- and Post-9/11." Master's thesis, Naval Postgraduate School, 2011.
- "MARADMIN 191/12: Inactive Duty Training Travel Reimbursement." U.S. Marine Corps, April 5, 2012.
<http://www.marines.mil/News/Messages/MessagesDisplay/tabid/13286/Article/110669/mcbul-1001-inactive-duty-training-travel-reimbursement.aspx>
- "MARADMIN 192/12: MCBUL 1500. Selected Marine Corps Reserve (SMCR) Prior Service MOS Retraining Program (PSMRP)." U.S. Marine Corps, April 5, 2012.
<http://www.marines.mil/News/Messages/MessagesDisplay/tabid/13286/Article/110668/mcbul-1500-selected-marine-corps-reserve-smcr-prior-service-mos-retraining-prog.aspx>
- "MARADMIN 230/12: MCBUL 7220. Change 1 To Fiscal Year 2012 (FY12) Selected Marine Corps Reserve (SMCR) Unit Officer Affiliation Bonus (OAB)." U.S. Marine Corps, April 20, 2012.
<http://www.marines.mil/News/Messages/MessagesDisplay/tabid/13286/Article/110632/mcbul-7220-change-1-to-fiscal-year-2012-fy12-selected-marine-corps-reserve-smcr.aspx>

- “Marine Corps Reserve Administration Management Manual.” MCO 1001R.1K.
Quantico: VA, U.S. Department of the Navy, 2009.
- “Memo-01.” U. S. Marine Corps. Deputy Commandant, Manpower & Reserve Affairs.
Quantico: VA, U.S. Department of the Navy, October 2012.
- Meyers, Eric W. “Reserve Officer Manpower Brief (as of 30 September 2012).”
Quantico: VA, U.S. Department of the Navy, October 2012.
- Nguyen, Van Q. “Analysis of the U.S. Marine Corps’ Steady State Markov Model for
Forecasting Annual First-Term Enlisted Classification Requirements.” Master’s
thesis, Naval Postgraduate School, 1997.
- “President’s Budget FY12 RPMC Pie Chart.” Quantico, VA: Department of the Navy,
2012).
- Pergar, Nick. “Reserve Manpower Brief (as of 30 September 2012).” Quantico: VA, U.S.
Department of the Navy, October 2012.
- Price, Jonathon D. “Effects of Activation on Selected Marine Corps Reserve Prior
Service Enlisted Continuation Rates in the Post-9/11 Era.” Master’s thesis, Naval
Postgraduate School, 2010.
- Price, Jonathan, Kyle Hahn, Jeremy McLaughlin, and Rachel T. Silvestrini. “Optimizing
Promotion Opportunity and In-Zone Range for the Unrestricted Marine Corps
Reserve Officer Population.” *Military Operations Research* 17, no. 4 (2012): 25-
38.
- Reamy, Stephen J. “Optimal Career Progression Of Ground Combat Arms Officers
In The Marine Reserve.” Master’s thesis, Naval Postgraduate School, 2012.
- Sales, Pauline. “The Validity of the Markov Chain Model for a Class of the Civil
Service.” *Journal of the Royal Statistical Society* 20, no. 1 (March 1971): 85–110.
- Sapp, Jeffrey K. “A Calculator Adaptation of the Markov Chain Model for Manpower
Analysis.” Master’s thesis, Naval Postgraduate School, 1983.
- Schumacher, Joseph F. “Forecasting Retention in the United States Marine Corps
Reserve.” Master’s thesis, Naval Postgraduate School, 2005.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
Ft. Belvoir, Virginia
2. Dudley Knox Library
Naval Postgraduate School
Monterey, California
3. Marine Corps Representative
Naval Postgraduate School
Monterey, California
4. Major Chad W. Seagren, USMC
Naval Postgraduate School
Monterey, California
5. Deputy Commandant, Manpower and Reserve Affairs
Quantico, Virginia
6. Director, Reserve Affairs Division
Quantico, Virginia
7. Dr. Michelle Dolfini-Reed
Center for Naval Analysis
Alexandria, Virginia
8. SgtMaj Gary Lee, USMC (Ret.)
Center for Naval Analysis
Alexandria, Virginia